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Nationwide Urban Runoff Program
An Evaluation of the Water Quality
Effects of Detention Storage and Source Control

Northeastern Illinois Planning Commission
Chicago

Prepared for

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This report evaluates the water quality effects of detention storage and source control for six specific constituents related to urban runoff - TSS, Cl, P, Cu, Pb, and Zn. The study site was a 45 acre-foot lake, Lake Ellyn, which drains a 534 acre urban watershed. While event mean influent to lake constituent concentrations for P, dissolved P, Cu, Pb, and Cl violated Illinois General Use Water Quality Standards, effluent event mean concentrations from the lake only violated the standard for P. Substantial reductions in suspended stormwater pollutants were noted for all monitored events as a result of detention in Lake Ellyn.

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NATIONWIDE URBAN RUNOFF PROGRAM

AN EVALUATION OF THE WATER QUALITY EFFECTS OF DETENTION STORAGE AND SOURCE CONTROL

FINAL REPORT

Prepared for

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Prepared by

NORTHEASTERN ILLINOIS PLANNING COMMISSION

DONALD L. HEY
Principal Investigator
and
GARY C. SCHAEFER
Project Coordinator

August 1, 1983

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NATIONWIDE URBAN RUNOFF PROGRAM

AN EVALUATION OF THE WATER QUALITY EFFECTS OF DETENTION STORAGE AND SOURCE CONTROL

NORTHEASTERN ILLINOIS PLANNING COMMISSION

DONALD L. HEY
Principal Investigatoar
and
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Project Coordinator

ABSTRACT

The sources and fate of constituents in urban stormwater runoff were monitored to determine the ability of wet bottom detention storage to retain pollutants and to assess the potential for keeping these pollutants out of urban stormwater through source control.

The study site was a 45 acre-foot lake, 10 acres in area named Lake Ellyn, located in Glen Ellyn, Illinois. A 534 acre urban watershed drains to the lake. Monitoring programs included atmospheric deposition (both precipitation and dryfall), vegetation, soils, domestic and public works chemical use, roof runoff, road dirt, catch basins, lake influent, sediment, water column and effluent.

Materials budgets were prepared for six constituents; TSS, Cl, P, Cu, Pb, and Zn at key points in the watershed; rooftops, pervious areas, impervious areas, catch basins and the lake. These budgets were then summed to yield a budget for the total watershed. Based on these budgets, it appears that the principal sources of solids are soil erosion and street surface decomposition. The principal source of P was vegetation; Cu and Pb, traffic; Cl, road salt; and Zn, roof runoff and traffic.

Eighty-three percent of the material in the urban runoff was less than 63 microns in size. Little accumulation of material in this size range was observed in either catch basins or street sweeper hoppers. Ninety-eight percent of the material leaving the lake was less than 63 microns in size. Event mean influent to lake constituent concentrations violated Illinois General Use water quality standards for P, dissolved P, Cu, Pb and Cl. Effluent event mean concentrations from Lake Ellyn violated the P standard only. Based on actual observation and influent event mean concentrations, urban stormwater does not appear to be toxic to fish in Lake Ellyn.

Project conclusions were that catch basins and street sweeping were ineffective urban stormwater pollutant management techniques and that although a good basic source control program (i.e. erosion control, careful use of chemicals) is beneficial for keeping pollutants out of urban stormwater, additional effort would not yield much benefit due to the diversity of sources and the inability to control certain sources (i.e., traffic, street salt).

Substantial reductions in suspended stormwater pollutants as a result of detention in Lake Ellyn were noted for all monitored events. Reductions in suspended solids and metals, were greater than 80 percent. Reductions in BOD_5, COD, and total phosphorus were greater than 50 percent. No reductions in chloride, dissolved solids, or ammonia were noted.

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"Young man," laughed the farmer,
"You're sort of a fool!
You'll never catch fish
In McElligot's Pool!"
"The pool is too small.
And, you might as well know it,
When people have junk
Here's the place that they throw it.
"You might catch a boot
Or you might catch a can.
You might catch a bottle,
But listen, young man...
If you sat fifty years
With your worms and wishes,
You'd grow a long beard
Long before you'd catch fishes!"

-- Dr. Seuss

CHAPTER 1: INTRODUCTION

Today, we are as a society somewhat more mindful of our streams, rivers and lakes than portrayed by Dr. Seuss in McElligot's Pool. The occasional shopping cart or old tire can still be seen in our urban rivers and lakes, but wanton dumping of refuse and wholesale contamination, by industries and municipalities alike, are pretty much in the past. While we are more conscientious and sophisticated about our environment and water resources, only the more visible consequences of our urban activities have been ameliorated. Every year, for example, close to a million tons of dissolved and suspended contaminants (all of it smaller in size than a pebble) leave urban watersheds in northeastern Illinois and enter the surface water environment as a result of stormwater runoff.

By this means, the total solids entering Lake Ellyn, the subject of this report, are estimated to be 477 tons or 954,000 pounds per year. This is equivalent in mass to 214 American made motor vehicles. There is enough dissolved and suspended zinc entering the lake to construct three motor vehicles and enough copper to build one. This is not to say that motor vehicles are the primary source of these contaminants, although they contribute their fair share. The comparison is made simply for perspective.

Automobiles are not dumped in whole or in small pieces into Lake Ellyn (in fact the lake is an attractive community asset). However, the automobile and a number of other urban necessities such as streets, houses and buildings contain materials which weather and decompose. It is the residues of these materials, often in the form of minute particles, along with soil and decaying vegetal matter and numerous chemicals used in the urban environment, which are transported by stormwater through gutters, across lawns and parkways, along streets and curbs, and through the storm sewers to urban lakes and streams -- like Lake Ellyn and its receiving stream, the East Branch of the DuPage River.

While the mass of material being washed from the Glen Ellyn watershed may appear to be large, and in truth it is, it is considerably less than the mass of soil, alone, lost from agricultural watersheds in northeastern Illinois. This loss has been estimated to be greater than 4.0 tons per acre per year (Northeastern Illinois Planning

Commission, 1979). Considering total solids, both suspended and dissolved, the erosion and loss of materials from the Glen Ellyn watershed amounts to 0.89 tons per acre per year. Agricultural erosion is over four times greater.

Not all the materials washed from an urban watershed are chemically active. In fact, the majority of the materials are inert, being comprised of such elements as silicon and calcium or such materials as sand, silt and clay. The active constituents range from exotic chemicals used for weed and pest control which, of course, can be highly toxic to aquatic life, to the more mundane substances such as phosphorous and nitrogen.

The active substances dealt with in this report can be grouped into four categories: nutrients, oxygen demanding materials, heavy metals and miscellaneous. The nutrient category includes phosphorous, nitrate and nitrites. The oxygen demanding substances are represented by such measures as biochemical oxygen demand, chemical oxygen demand, total organic carbon and ammonia. Copper, lead and zinc are the principal heavy metals which were investigated. Finally, chloride, and the United States Environmental Protection Agency's priority pollutants are contained in the last category.

These contaminants vary in their environmental effects. The inert substances are by nature chemically benign, but they can and do physically affect streams and lakes by settling to the bottom and smothering more desirable materials and aquatic life. The nutrients often cause luxurient growths of nuisance plants such as algae. The oxydizable materials rob urban waters of life supporting dissolved oxygen. Heavy metals, in sufficient concentration, can be acutely toxic to aquatic life as can many of the more exotic chemicals such as found in pesticides and herbicides.

Stormwater and the associated contaminants emanating from urbanized areas have been identified as contributing to the observed, persistent violation of the state water quality criteria for streams in northeastern Illinois (Northeastern Illinois Planning Commission, 1979). The materials carried by stormwater runoff have caused the eutrophication of local streams and lakes, the degradation of aquatic habitat, and the impairment of recreational uses of surface waters in as far as these benefits were afforded by the natural conditions.

The effects of urban runoff are both immediate and long term. Dissolved oxygen can be depleted due to shock loads of deoxygenating waste. The suspended, particulate matter, which eventually settle to the stream or lake bottom, can eventually release the attached heavy metals, pesticides, deoxygenating materials, and other sediment related chemicals months and even years later.

Although fish and other forms of aquatic life survive in the urban waters of northeastern Illinois, their biological quality is relatively poor as compared to pre-development populations or those found in rural waters (Brigham, 1978). Fish diversity is quite low and the presence of blue-green algae is widespread, although in some cases even algae are limited in urban waters due to turbidity. Lake Ellyn is a good example, exhibiting relatively turbid waters while supporting some fish species, albeit sunfish and goldfish, and limited algal populations.

There is yet another important consideration in isolating and evaluating the effects of urban stormwater runoff and that is the chemical and biological constraints imposed by the physical configuration of urban drainage systems and receiving waters. If not closed conduits, most open drains and streams in northeastern Illinois are channelized and wetlands and floodplains have been filled. Consequently, water depths have been increased which has reduced the assimilative capacity of the local streams. Combined with this long detention times due to the naturally low stream gradients in the region, and the significant urban waste loads has resulted in a generally poor aquatic environment.

Further, it was observed during the course of the Glen Ellyn study that the concentrations of contaminants reaching the lake during storms and in the lake itself were well below toxic levels. The environmental state of our urban streams and lakes must then be a combination of sublethal or chronic chemical contamination and morphology. Consequently, if the deleterious effects of urban stormwater are to be mitigated or controlled, short of collecting and treating urban stormwater in the traditional point source manner, three courses of action are possible:

1. Exclude contaminants from urban stormwater runoff either by controlling the source of contamination or removing contaminants at a control point (i.e., roofs, pervious and impervious surfaces, catch basins, and the lake);
2. Select downstream locations for immobilizing the materials with the idea that they would ultimately be removed and disposed of in some other fashion;
3. Change the morphology of our urban streams and lakes in order to increase their assimilative capacity;

The objectives of the Glen Ellyn study were to evaluate the first two: the potential for excluding contaminants from stormwater by controlling their sources or removing them at control points upstream of Lake Ellyn and the efficacy of using Lake Ellyn as the short- and long-term point of immobilization.

Background and Summary Findings

With the passage of Public Law 92-500 (the Federal Water Pollution Control Act Amendments of 1972) the federal and local governments focused on the goal of cleaning up our streams and rivers. Funds were provided under Section 208 of this law to develop comprehensive water quality management plans, explicitly recognizing the importance of nonpoint sources, such as urban stormwater runoff, and thereby lowering, somewhat, the status of point source control as a means for achieving the objectives of "fishable and swimmable". The Northeastern Illinois Planning Commission, and other similar local and state organizations who were responsible for developing the plans, soon discovered a lack of knowledge regarding the nature of urban stormwater problems. Lacking this knowledge but yet recognizing the need to produce a plan, the commission recommended solutions based, in large, on theory.

Given the lack of knowledge, the uncertainty of the control technologies, and the enormity of the estimated cost of urban stormwater control programs, in 1977, federal funding for treatment of separate storm sewer discharges was denied with the passage of Public Law 95-217. In the following year, the United States Environmental Protection Agency undertook its Nationwide Urban Runoff Program.

The program is intended to investigate urban stormwater problems and to evaluate alternative control strategies. Twenty-eight projects were selected by the agency to reflect the different climatic, topographic and urban conditions found throughout the country. Collectively, the results from these studies are intended to provide the understanding lacking during the 208 program and thereby promote local plans for urban stormwater management.

Although each project is addressing issues of particular importance to its region, the results are intended to have nationwide application.

As with the other projects, the objectives of the Lake Ellyn Study were uniquely tailored to conditions and problems in northeastern Illinois. Source control and detention treatment were considered, prior to the Lake Ellyn Study, to offer the greatest potential at the least cost for urban stormwater control. The Northeastern Illinois Planning Commission's 208 plan recommends a number of technical strategies for controlling urban stormwater runoff: street sweeping, performance zoning, and detention treatment (Northeastern Illinois Planning Commission, 1979). The bases for these recommendations were theoretical studies or test programs from other locations in the country. For example, the recommendations concerning street sweeping equipment and efficiencies were derived from studies by the U.S. Environmental Protection Agency (Sartor, 1972) and Stanley Consultants (Stanley, 1977). The effectiveness of detention basins was derived by assuming theoretical particle size distributions and settling rates. The Commission undertook the evaluation of performance zoning (i.e., the maximization of pervious surface vis-a-vis impervious), relating the efficiency of the watershed and the amount of materials delivered to the stream to the amount of impervious area (Lake County Regional Planning Commission, 1978), because of time and monetary limitations, the evaluation was based on mathematical simulation. While each study indicated the relative benefit of the subject control strategy, none of them provided conclusive evidence that the particular strategy would produce, in reality, the desired result. These studies were not linked to actual field conditions, the information for this vital linkage simply was not available.

One possible control measure which was not specified in the commission's 208 plan was source control - time and money again being the limiting factors. It was not possible, from the available data to construct the necessary mass balances of materials (e.g., nutrients, sediments, heavy metals, etc.) that would be necessary to evaluate the relative benefit of one control program versus another. If control measures were to be recommended, the sources of contaminants (e.g., air, vegetation, animal or soils) needed to be identified -- this has been accomplished in the Lake Ellyn study.

At the outset of the Lake Ellyn study, there was reason to believe that the ultimate urban stormwater control program would involve, to some degree, a combination of the four strategies previously mentioned. However, due to climatic conditions, it appeared that street sweeping would have little effect on the overall quality of urban stormwater. This has proven to be the case not only because of climate but because of the relative inefficiency of street sweeping in removing the smaller, more important particles. As with street sweeping, catch basins proved ineffective because of insufficient detention time. The control of contaminants from roof surfaces by means of detention on and infiltration into pervious surfaces is limited by the fact that most of the runoff reaching the sewer system comes from commercial roofs which are not proximate to such surfaces. Detention treatment has emerged from the study as a viable means of removing and immobilizing stormwater contaminants. In some regards it is not as effective as initially envisioned but it certainly improves the quality of water moving through the detention basin en route to the receiving stream. There remain important questions of management but the overall effects are positive --- it is just a matter of whether a community wishes to immobilize its urban stormwater contaminants at such a location. Finally, source control, in the absence of behavorial modification, appears not to be a viable solution. The contaminants in urban stormwater runoff come from so many sources in such small relative quantities that the elimination of any one would have no appreciable effect or improvement on the resulting washoff. Without substantially modifying the social, economic and physical structures of our urban communities, source control, except in the case of outright toxic substances, is not a reasonable solution.

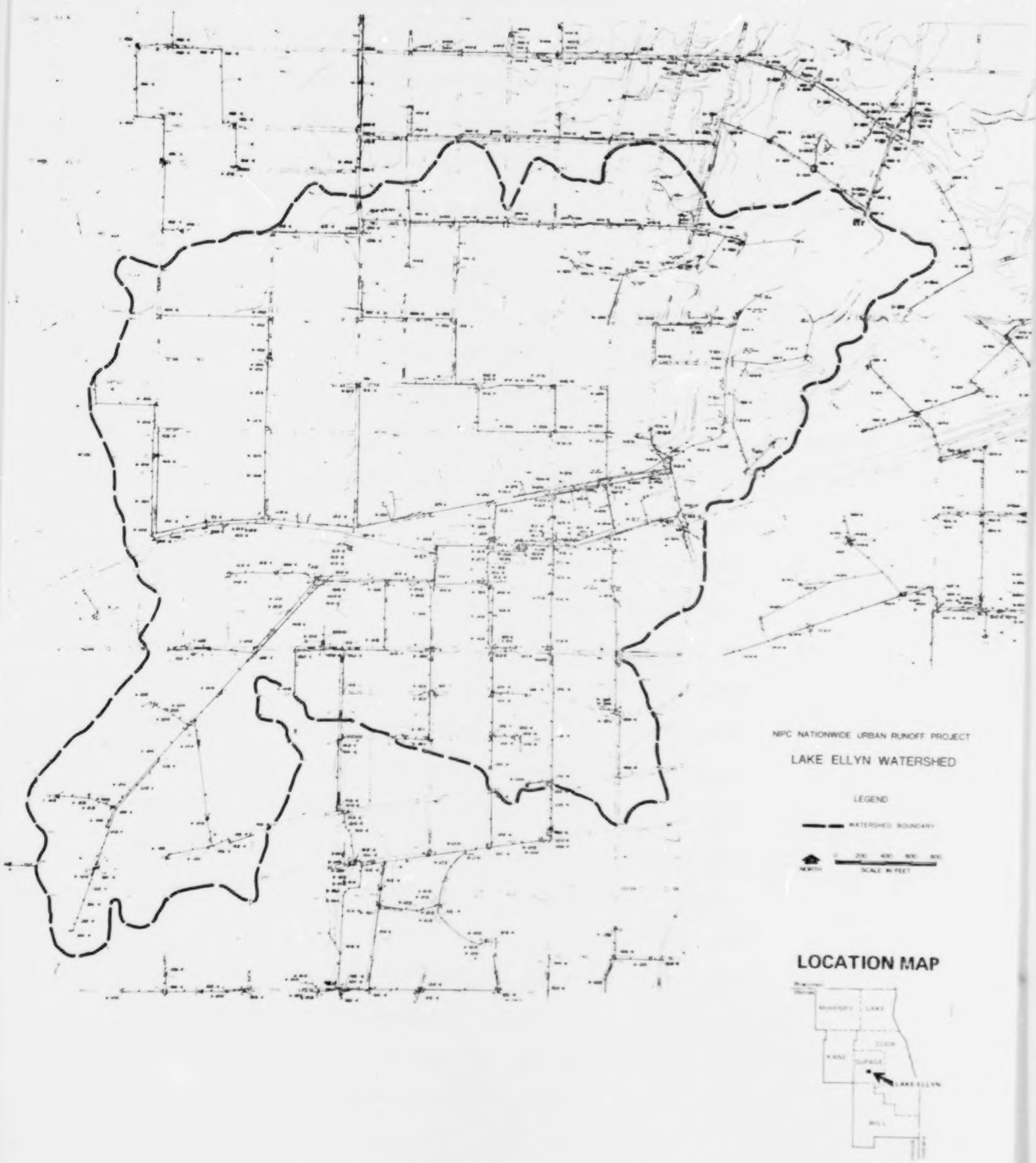
While these conclusions, of course, directly pertain to the study area, the Lake Ellyn Watershed, there is no reason to believe they would not or do not apply to any and all urban areas in northeastern Illinois or, for that matter, to any urban environment within the same climatic region. It was the intention of the study to produce data and information about the characteristics and control of urban stormwater which could be extended to other areas. Hopefully, this objective has been achieved.

Site Selection

Lake Ellyn and the community in which it is located, Glen Ellyn, Illinois, are located 14.5 miles west of Chicago, see Figure 1-1. The selection of Lake Ellyn and its urbanized watershed was guided by the following criteria:

1. The drainage area and detention facility should be located in the head waters of a perennial receiving stream, eliminating the need to evaluate boundary conditions;
2. No point sources or combined sewers should be tributary to the detention basin;
3. The detention basin (either wet or dry bottom) should be in place and operational;
4. The tributary urban area should be as large as possible, or certainly dominant, in order to avoid interferance from other land uses (e.g., agricultural);
5. The study area should be within a watershed which had been previously studied by the Commission and as close as possible to previous water quality and other sampling sites;

FIGURE 1-1: SITE LOCATION


NIPC NATIONWIDE URBAN RUNOFF PROJECT
LAKE ELLYN WATERSHED
LEGEND
WATERSHED BOUNDARY
NORTH
0 200 400 600 800
SCALE IN FEET
LOCATION MAP
WISCONSIN
ILLINOIS
McHENRY
LAKE
KANE
COOK
DUPAGE
LAKE ELLYN
WILL

6. Sampling locations should be accessible and easements for the installation and operation of sampling equipment readily obtainable;
7. The tributary stormwater collection system should be well defined and properly operating;
8. The selected watershed and receiving stream should have demonstrated stormwater related problems;
9. A typical urban land use mix should be represented.

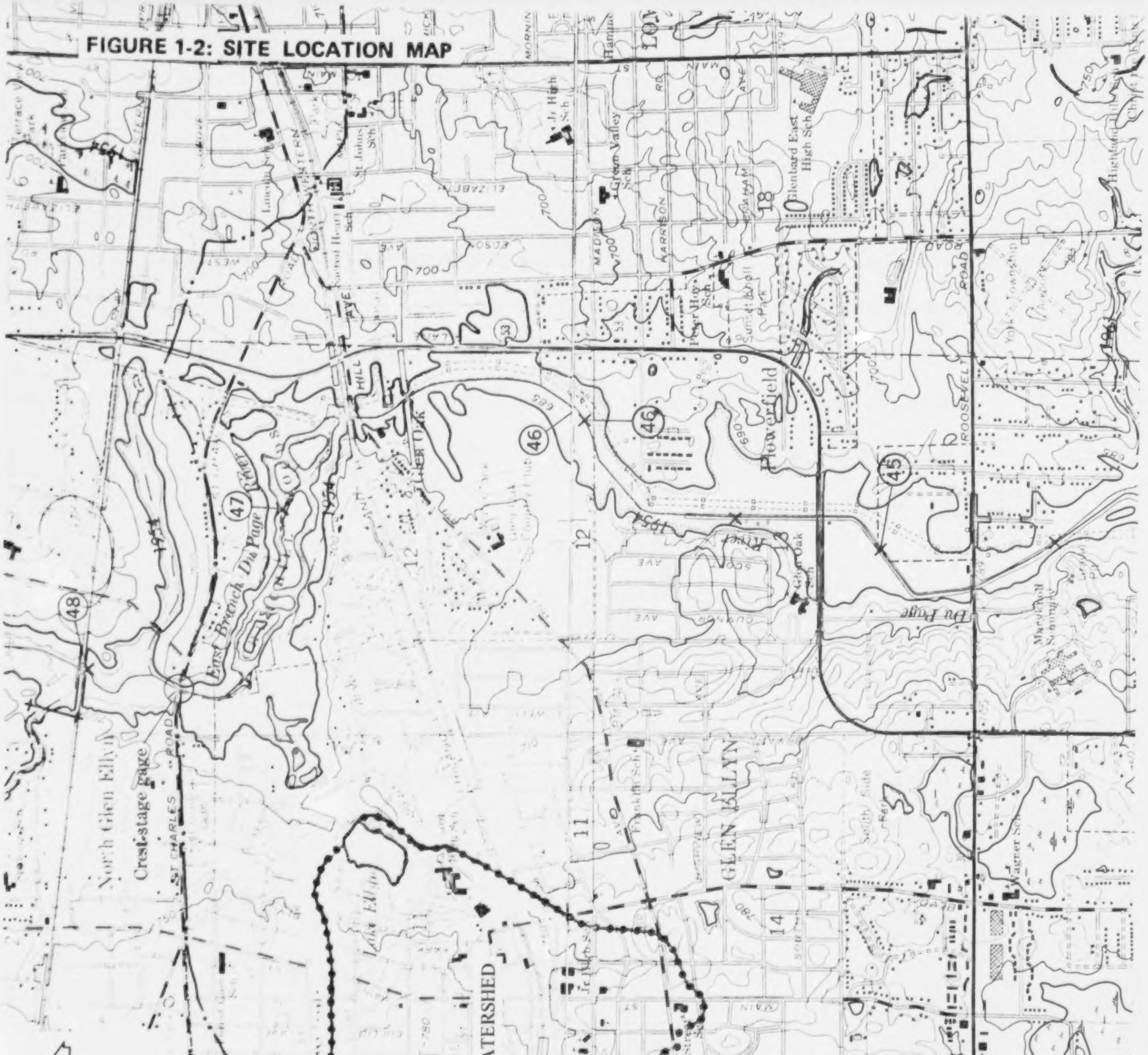
The first and second criteria all but eliminated the second and higher ordered streams in northeastern Illinois because of substantial boundary conditions and the presence of point sources and combined sewers. Moving too far from the heavily urbanized, central area, however, conflicted with criterion three because of the prevalence of agricultural land uses in the outlying areas. The fourth and fifth criteria directed the selection process to the DuPage River Basin because the commission has conducted numerous studies during and subsequent to the 208 program. As a result, a list of some 70 stormwater detention facilities, mostly wet bottom, in DuPage County was drawn up.

With the assistance of county personnel and personnel of United States Geological Survey, the Commission staff evaluated each of the 70 proposed detention facilities. This evaluation involved site visits and ranking of each site relative to the above criteria. Many of the sites were rejected because of difficulty in protecting or setting up the necessary sampling equipment or because of construction in the tributary area. Lake Ellyn and its tributary watershed best fit the above criteria and they have provided excellent test conditions.

After Lake Ellyn had undergone technical scrutiny, the responsible management agencies were notified of the study and asked to participate. The Village of Glen Ellyn readily accepted as did the Glen Ellyn Park District, under whose authority the lake falls, and the Glenbard School District No. 87 on whose land some of the sampling equipment needed to be installed. Permission was acquired for constructing the monitoring shelters and installing the monitoring equipment. Figure 1-2 gives the location of the watershed relative to the East Branch of the DuPage River and the location of the lake relative to its drainage area.

As with the technical conditions, the selected site proved to be excellent because of the cooperation provided by park district and village personnel. This cooperation was exemplified by an instance where, halfway through the study, the village issued contracts to construct two relief storm sewers to the lake. After meeting with the village staff and discussing the situation with the director of the park district and U.S. Environmental Protection Agency representatives, the village agreed to help attach new monitoring equipment to one sewer and bulkhead the other until the study was completed.

FIGURE 1-2: SITE LOCATION MAP


LAKE ELLYN WATERSHED
GLEN ELLYN
North Glen Ellyn
Crest-stage gage
Lake Ellyn
East Branch Du Page River
Du Page
Flowerfield
Glenbard East High Sch
Glen Oak Country Club
Main Street Sch
Lincoln Sch
Franklin Sch
Hawthorne Sch
St Petronille Sch
Jr High Sch
Wagner Sch
Marywood Sch
St Charles Road
Roosevelt Road
Hill Ave
Main
Blanchard
Elizabeth
Karrison
Madison
Crescent
Pershing
Western
York Township
Highland Hills
St Johns Sch
Green Valley Sch
Sunset Knoll Park
Sunset Park
Sacred Heart Sch
Lincoln Sch
Terrace View Park
Glenbard East High Sch
700
750
760
770
780
1954
45
46
47
48
7
10
11
12
14
15
18
SCALE 1:24 000
0
½
1 MILE
CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

There was also support in the form of local high school teachers and students becoming interested and involved in the project and many citizens following the development and execution of the study. As evidence of the community's involvement, interest and respect for the project, little or no vandalism occurred to the numerous pieces of monitoring equipment located in full view at the lake and at other locations in the watershed.

The Monitoring Programs

The monitoring programs were designed to define the major sources and measure the materials transported by stormwater and the movement of these materials through the watershed and into and through the lake. The input sources were divided into eight generic categories: the atmosphere, traffic, domestic chemicals, animals, vegetation, pavement decomposition, decomposition of building materials, soils, and public works chemicals. The movement of materials through the basin was monitored at four general locations: roofs, streets, catch basins and the lake. Some monitoring activities, for example the determination of home use of chemicals, simply involved a one-time-only survey. Others required a great deal more attention and were far more detailed. For example, the measurement of precipitation was conducted on a five-minute interval for the duration of the sampling program which lasted 18 months. Each monitoring activity in terms of scope and intensity was designed to provide the relative degree of detail necessary to assess the importance of the source or control point under consideration.

The monitoring programs involved numerous agencies and personnel. The commission attempted to employ recognized experts or individuals with firsthand knowledge regarding the monitored phenomenon. The organizations that participated in the monitoring programs and the general nature of these programs are given in Tables 1-1 through 1-3.

Collection of atmospheric data (including deposition of materials, both wet and dry, and precipitation) began in November, 1979 and extended through August, 1981. The Illinois State Water Survey, Atmospheric Science Section, was responsible for the collection and chemical analyses from the start of program through March, 1981. Following this date to the completion of the study, a private laboratory performed the chemical analyses. Data were collected at two locations in the watershed, see Figure 1-3. The western site was located within a chain linked fence surrounding a Commonwealth Edison Company power substation. Equipment at this site included one wet/dry collector, one bulk collector, and one shielded, recording, precipitation gauge. The eastern site was on the roof of the Glenbard West High School. A single bulk precipitation collector was used at this site. Samples were collected weekly from the wet/dry and the bulk collectors.

The quantities of material emanating from motor vehicles

Table 1-1: Source Monitoring Programs

	Responsible Agent[1] Collected	Analyzed	Means
Atmosphere			
Precipitation	ISWS/USGS	ISWS/USGS Private	Measured
Dry Fall	ISWS/Private	ISWS/ Private	Measured
Traffic	GEPWD/NIPC	NIPC	Measured
Domestic Chemical Usage	DCRPC	NIPC	Questionnaire
Animals	IDOC/DCRPC/NIPC	IDOC/NIPC	Questionnaire Survey
Vegetation	DCRPC	NIPC/DCHD	Aerial Photographs, Survey, Measured
Pavement and Construction Decomposition	NIPC	DCHD/ Private	Measured, Estimated
Soils	NIPC	DCHD/ Private	Measured
Public Works Chemical Usage			
Deicing Agents	GEPWD/NIPC	DCHD	Measured
Other	GEPWD	NIPC	Estimated

[1] Private = individual or company other than a government agency.
USGS = U.S. Geological Survey
ISWS = Illinois State Water Survey
GEPWD = Glen Ellyn Public Works Department
NIPC = Northeastern Illinois Planning Commission
IDOC = Illinois Depepartment of Conservation
DCRPC = DuPage County Regional Planning Commission
DCHD = DuPage County Health Department

Table 1-2: Control Point Monitoring Programs

	Responsible Agent[1] Collected	Analyzed	Means
Roofs			
Surfaces	DCRPC	NIPC	Survey
Washoff	Private	DCHD/ Private	Measured
Streets			
Surfaces	GEPWD/DCRPC	NIPC	Survey
Road Dirt	NIPC	DCHD/ Private	Measured
Snow	NIPC	DCHD/ Private	
Catch Basins			
Volume	NIPC	NIPC	Survey
Residual Material	NIPC	DCHD/ Private	Measured
Lake			
Inflow/Outflow	USGS/ Private	USGS DCHD	Measured
Insitu Water	ISWS	ISWS/DCHD	Measured
Sediment	ISWS/Private	ISWS/Private	Measured

---

[1] See Footnote 1 in Table 1-1.

Table 1-3: Miscellaneous Monitoring Programs

	Responsible Agent[1] Collected	Analyzed	Means
Settling Velocity	NIPC	Private	Measured
Groundwater	USGS	USGS	Measured
Priority Pollutants	USEPA	USEPA	Measured

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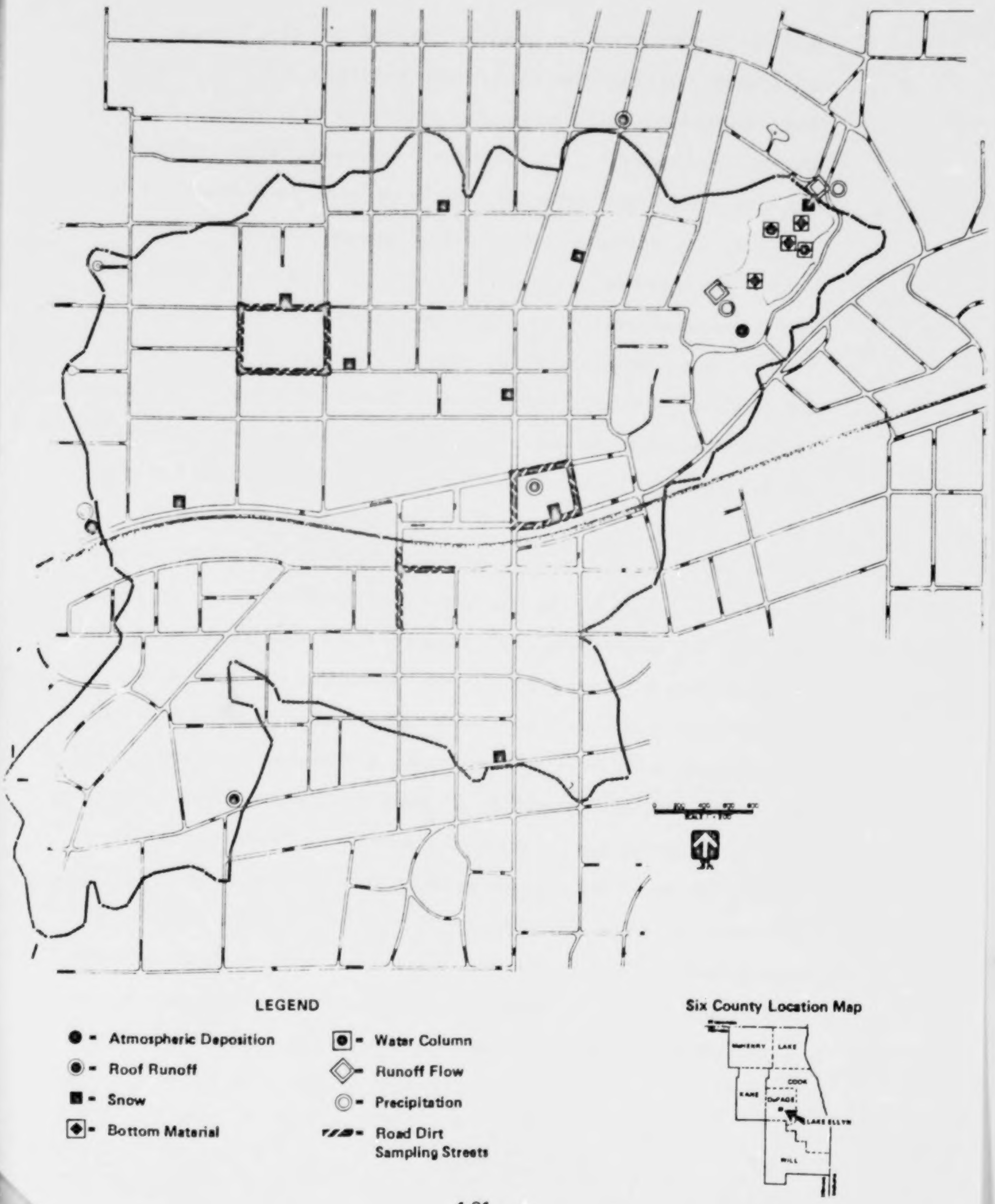
[1] USEPA = U.S. Environmental Protection Agency, for others see Footnote 1 in Table 1-1.

FIGURE 1-3: LAKE ELLYN WATERSHED MONITORING POINTS


LEGEND
● - Atmospheric Deposition
◉ - Roof Runoff
■ - Snow
◈ - Bottom Material
▣ - Water Column
◇ - Runoff Flow
◎ - Precipitation
▨ - Road Dirt Sampling Streets
Six County Location Map
McHENRY
LAKE
COOK
KANE
DuPAGE
LAKE ELLYN
WILL

was estimated based on traffic volumes and the distribution of traffic within the basin and emission characteristics. The conditions were obtained from the Glen Ellyn Public Works Department. The chemical characteristics of motor vehicle emissions were derived from test data reported by the U.S. Environmental Protection Agency (Shaheen, 1975).

The monitoring or determination of domestic chemical usage focused primarily on three categories of chemicals: fertilizers, herbicides and pesticides, and deicing agents. Estimates were derived for all three of these chemical categories based on the response to a mail survey conducted by personnel of the DuPage County Regional Planning Commission. A copy of the survey is contained in Appendix A.

The contribution to the contamination of urban stormwater runoff by animals is, in the final analysis, quite small except for phosphorous. However, at the outset of the investigation it was felt their contribution should not be overlooked; consequently, the domestic animal population was estimated by means of the same questionnaire mentioned above, by an actual count of geese and ducks which inhabit the lake during the migratory seasons, and from estimates of small animal urban populations provided by the Illinois Natural History Survey. In addition, a fish survey was conducted in June, 1980 to assess the habitability of Lake Ellyn and to better define the recreational potential of the lake. This was done by the Illinois Department of Conservation.

Both in urban and natural settings, trees and other plants generate substantial materials, some of which move across the land's surface and through the drainage system to streams and lakes --- most of these materials are removed by refuse collection in urban areas. Glen Ellyn is an older suburban community and is shaded by large, mature trees with the predominate tree type being maple. The DuPage County Regional Planning Commission undertook the mapping of the vegetal cover and the DuPage County Health Department performed the chemical analyses on the materials. The analyses were done on three categories of vegetal matter: leaves, seeds and parkway grasses. Care was taken to insure that all surface deposits were removed before the analyses were undertaken.

To estimate the relative contribution of construction materials, direct measurement of the chemical composition of materials was used on the one hand and analysis of residuals on the other. The materials used for the construction of the impervious surfaces (including streets, driveways and parking areas) were sampled and analyzed. The residuals were analyzed by means of an extensive road dirt sampling program, the sampling of roof runoff and the sampling of catch basin sediments. These programs are discussed below and in detail in Chapter 5.

Although the soils in the watershed are not highly erodible and, in any event, they are well protected by grass and impervious cover they nevertheless contribute to the total contaminant load reaching the lake. The soils were classified and chemical analyses undertaken on the soils themselves as to their chemical composition and as to the characteristics of soil leachate.

By far, road salt, NaCl, represented the greatest chemical usage by the Glen Ellyn Public Works Department during the study. The tons used by snow event were reported by the department and the salt itself was chemically analyzed for trace contaminants. No herbicides or pesticides usage was reported by the department in the watershed during the study period.

The next category of monitoring programs included measuring the residuals and the material fluxes at the four control points: roofs, streets, catch basins and the lake. The runoff on various categories of roofs (e.g., commercial and residential) was sampled and analyzed. Over 3,000 road dirt samples were taken and composited, resulting in 91 analyses. The road dirt samples were stratified according to the state of repair of the street and traffic density. Each stratification was further stratified by particle size: [63u, 63 to 250u and |250u. The data resulting from the road dirt monitoring program were used to determine the amount of materials available for washoff at any time and the chemical characteristics of the road dirt.

Catch basins were randomly sampled throughout the watershed for both depth and chemical characteristics of sediment. These samples were stratified by the same particle size categories as for road dirt. Using the measured depth and density of materials at the beginning and end of the study period, an estimate of constituent removal by the catch basins over the study period was derived.

The most extensive and perhaps the most significant monitoring program was that of measuring the quantity and quality of stormwater runoff entering and leaving the lake. This was done by the U.S. Geological Survey. Flow monitoring and sampling equipment were installed at the outlet of the main sewer entering the lake. This sewer drains approximately 73 percent of the watershed. The remaining 27 percent of the watershed is controlled by three much smaller storm drains. One hundred percent of the outflow was measured. The data resulting from this monitoring program served to characterize the chemical quality of urban stormwater and to check and close the constituent budgets constructed for the various control points. Outflow water quality measurements were corroborated by measurements of water quality within the lake itself. Lake sediments were surveyed, sampled and analyzed by the Illinois State Water Survey, Water Quality Section and a private contractor. This was done to further check the estimates of materials entering and leaving the lake. Chemical analyses were performed on the previously mentioned particle size classes.

Miscellaneous monitoring programs included settling velocity tests, measuring the exchange of water between the lake and groundwater, and priority pollutants. The latter two programs proved insignificant. There appears to be little or no connection between the lake bed and the local groundwater table. This is due to the lake being underlaid by glacial deposits having a high clay content affording little or no movement of water. The priority pollutant analysis performed by the U.S. Environmental Protection Agency uncovered the existence of some priority pollutants, but their concentrations do not exceed the agency's criteria for the protection of fresh water aquatic life. On the other hand, the settling velocity tests played a significant role in the evaluation and development of detention basin design criteria. These tests were performed on composited stormwater samples drawn from the inlet. They revealed that a consistently short settling time, approximately four hours, was required for 95 percent removal of suspended materials. The short settling time is supported, in part, by the trap efficiencies observed for the lake.

An important component of all the monitoring programs was the set of constituents for which chemical analyses were performed. Table 1-4 gives the constituents which were evaluated at one time or another or at one location or

Table 1-4: Constituents Measured During Project

PARAMETERS	Atmospheric Deposition	Roof Runoff	Vegetation	Soils	Street Sweeping and Road Dirt	Catch Basins	Stormwater	Water Column	Sediment	Groundwater	Snow	Pavement	Road Salt
Suspended Solids	X	X				X	X	X		X	X		
Particle Size Distribution				X	X	X	X		X				
Specific Conductance	X	X				X	X	X		X	X		
Temperature							X	X					
Dissolved Solids	X	X				X	X	X		X	X		
Total N			X										
DO							X	X					
pH	X	X				X	X	X	X	X	X		
COD	X	X		X	X	X	X	X	X		X		
BOD$_5$		X	X		X	X	X	X			X		
Alkalinity							X			X			
Hardness							X	X		X			
Total NH_4	X	X		X	X	X	X	X	X		X		
Total $NO_2 + NO_3$	X	X		X	X	X	X	X	X		X		
Total Kjeldahl N	X	X		X	X	X	X	X	X		X		
Dissolved Kjeldahl N							X	X					
Total Phosphorous	X	X	X	X	X	X	X		X		X		
Dissolved Phosphorous							X						
Chlorides	X	X	X	X	X	X	X	X			X	X	X
Total Fe	X	X	X	X	X	X	X	X	X	X	X	X	X
Dissolved Fe	X						X	X					
Total Cd	X	X	X	X	X	X	X	X	X	X	X	X	X
Dissolved Cd	X						X	X					
Total Cr	X	X	X	X	X	X	X	X	X		X	X	X
Dissolved Cr	X						X	X					
Total Cu	X	X	X	X	X	X	X	X	X	X	X	X	X
Dissolved Cu	X						X	X					
Total Pb	X	X	X	X	X	X	X	X	X	X	X	X	X
Dissolved Pb	X						X	X					
Total Zn	X	X	X	X	X	X	X	X	X	X	X	X	X
Dissolved Zn	X						X	X					
Total As	X	X	X	X	X	X	X	X	X		X	X	X
Dissolved As							X	X					
Total Hg	X		X	X	X	X	X	X	X		X	X	X
Dissolved Hg	X						X	X					
Suspended Organic Carbon							X						
Dissolved Organic Carbon							X			X			
Oil and Grease							X						
Settling Velocity							X						
Ortho PO_4								X					
Priority Pollutants							X		X				
Total K	X						X			X			
Total Mg	X						X			X			
Total PO_4	X												
Total SO_4	X									X			
Total Na	X									X			X
Total Ca	X									X			
Volatile Solids					X	X			X				
Bottom Fauna									X				
Sediment Oxygen Demand									X				
Moisture Content						X			X				

another. Some of these constituents, or more properly, some of the measurements were dropped after they proved insignificant. For example, cadmium, chromium and mercury were dropped from stormwater analyses after it was determined that they were not present in detectable quantities. In the case of mercury, fairly high concentrations were found in the lake sediments, at least relative to the U.S. Environmental Protection Agency's "Guidelines for Classification of Sediments"; however, as nearly as could be determined, the presence of mercury in the sediments resulted from some past usage which was not occurring during the study period. Many of the other measurements were used to cross check the principal measurements which are cited in this report.

Study Conditions

One of the major concerns at the outset of the program was that mother nature would cooperate and that sufficient storms would occur for an adequate characterization of stormwater runoff. In this regard, the study period could not have been better. For the study year, for which most of the results are based (July 1, 1980 through June 30, 1981), the precipitation characteristics are amazingly similar to those of the long-term characteristics (see Table 1-5). Ninety-five storms occurred during the study year, depositing 38.0 inches of water. The mean storm, for this period, deposited 0.4 inches and had a duration of 4.05 hours. The time between storms was 87.1 hours. Based on 13 years of data from a nearby gauge, the mean precipitation is 35.6 inches per year deposited by 100 storms per year. The long-term, mean event deposited 0.34 inches and lasted for 4.56 hours. The mean dry period was 83.2 hours (see Table 1-5).

Except for the sewer construction project, which was previously mentioned, the watershed remained stable throughout the study -- of course, one of the criteria for selecting the Lake Ellyn site was that the watershed be fully developed. Public works practices such as street sweeping and catch basin cleaning continued pretty much as in previous years. A limited amount of street resurfacing occurred, but this was accepted as a normal, ongoing urban activity. The storm sewers intercept a minor amount of potable water supply leakage; however, this remained constant throughout the study period. No unusual spills or accidents occurred within the basin that were detected. This was perhaps fortunate for in past years this has not been the case. For example, a train derailment in Glen Ellyn caused the rupture of an ammonia tank car and the release of ammonia to the sewer system. The ammonia ultimately reached Lake Ellyn causing a fish kill and obviously had a major impact on the water quality of the lake. Also, in past years, there have been occasional events in the lake where algal populations reached nuisance levels resulting in dissolved oxygen problems. These

Table 1-5: -- Precipitation Conditions

	Study Year[a]	Long-Term Regional[b]
Means (inches/year)	38.0	35.6
Storm Frequency per Year[c]	95.0	99.7
Mean Storm (inches)	0.40	0.34
Mean Storm Duration (hours)	4.05	4.56
Mean Intra-Storm Duration (hours)	87.1	83.2

---

[a] Study year (July 1, 1980 through June 30, 1981)

[b] Thirteen year period (1964-76), O'Hare Airport

[c] A storm is defifned by one or more conservative hours having total precipitation 0.04 inches, with one hour of no precipitation beginning and ending a storm

events are reported to be rare, and they did not occur during the study. The conditions of the lake during the study were taken to be typical.

CHAPTER 2: THE WATERSHED

Topography

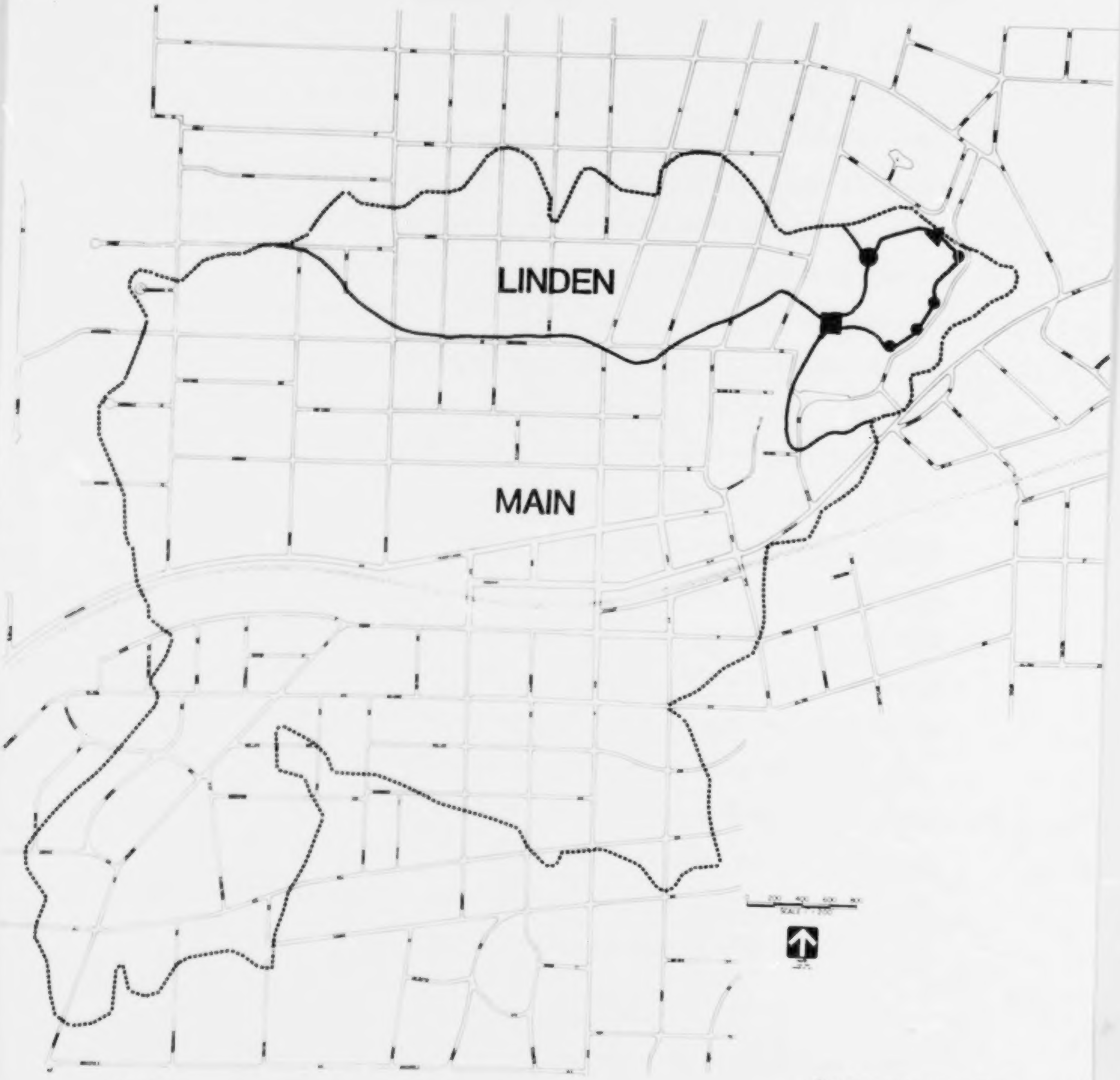
The Lake Ellyn watershed is characterized by rough, youthful topography, slightly dissected slopes and poor drainage. These features were formed during the most recent glacial period just prior to the retreat of the Wisconsinan glacier from Illinois. As a result of the glacial action, the basin is moderately sloped, 0.0417 feet per foot, except for locally prominent and much more steeply sloped kames on the east and southeast of the lake.

The natural topography has been altered little by urbanization except for the drainage features. Lake Ellyn straddles what was once the natural outlet of the basin. The storm sewers, on the other hand, have divided the watershed into three separate areas (see Figure 2-1). Some 73 percent of the watershed discharges at a single point into the lake and is termed the Main Watershed. A smaller watershed, termed the Linden Watershed, accounts for 18 percent of the area. Nine percent of the watershed is accounted for by the area immediately to the southeast of the lake and drains the kame which is located there.

Geology and Soils

The surficial glacial features of the watershed are composed of till, outwash and lucustrine sediments. These deposits and the remainder of the watershed are underlaid by the Wadsworth Till Member of the Wedron Formation. This

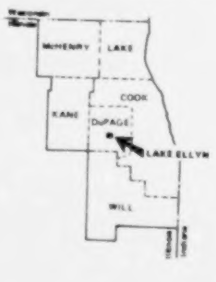
FIGURE 2-1: LAKE ELLYN DRAINAGE AREAS


LINDEN
MAIN

LEGEND

- ■ Main Watershed Inlet
- ● Linden Watershed Inlet
- ▲ Submerged and Surface Outlets
- • Minor Inlet

Six County Location Map


McHENRY
LAKE
COOK
KANE
DuPAGE
LAKE ELLYN
WILL

till formation is silty clay with a low content of pebbles and boulders (see Table 2-1). Sand, silt and gravel layers in the till are locally common but discontinuous. The depth of till is over one hundred feet. Other surficial deposits include the recent Cahokia Alluvium, which consists of some organic material, silt, clay, sand and sometimes gravel, and by the Batavia Member of the Henry Formation, characterized by sandy outwash. Urbanization has altered some of these deposits and added such materials as fill from dredged lake sediments.

The entire study area is underlaid by bedrock of the Silurian age. The uppermost strata are entirely dolomite. There are no outcrops of the formation within the study area, the nearest outcrop being some 12 miles southeast.

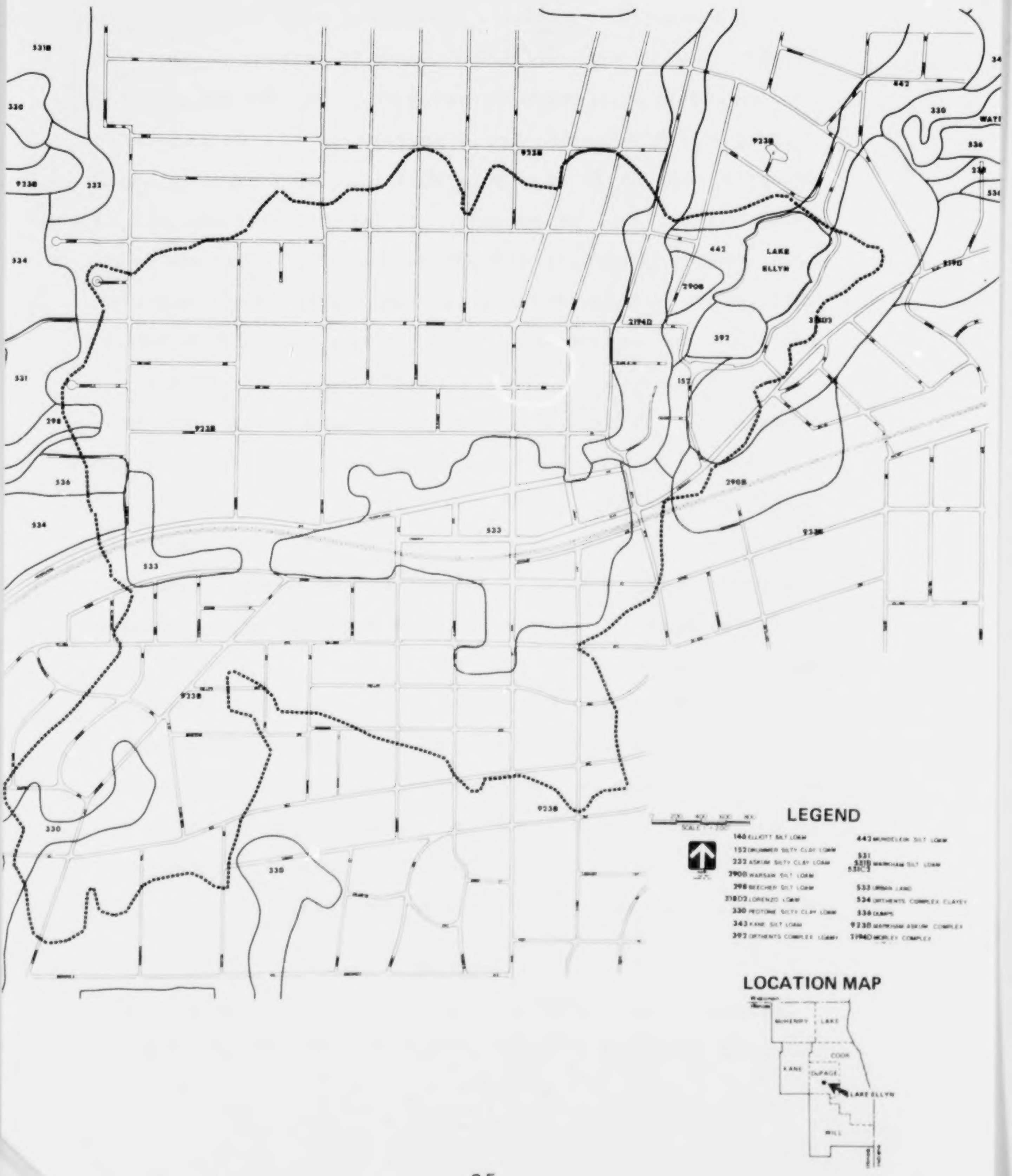
Eight different soil units have been identified within the watershed (see Figure 2-2). The most extensive, by far, is the urban land - Markham, Ashkum Complex (923 B) which covers 403 acres or 75 percent of the watershed. The Markham Unit is characterized by black silt loam at the surface. Within the basin, it occupies gentle slopes. Erosion can be a serious problem with Markham soils unless vegetative cover is maintained. Ashkum soil is characterized by nearly level terrain which often requires artificial drainage. The surface layer is approximately 11 inches of black silty clay loam. Beneath the surface layer is gray, very fine silty clay. The next most predominant land cover is Urban Land (533) which covers 65 acres of the watershed

Table 2-1: Soil Boring[1]

Strata	Thickness Feet	Depth Feet
Topsoil	0.5-1.5	1.5
Stiff brown clay	2.0	3.5
Stiff brown silty clay with a little fine to coarse sand	6.0-8.0	11.5
Hard gray silty clay with thin sand seams	10.0	21.5

[1] Patrick, 1981 and Calhoon, 1980

FIGURE 2-2: SOIL TYPES


531B
330
923B
232
534
531
298
923B
536
534
533
533
923B
923B
330
330
923B
442
330
536
LAKE
ELLYN
442
290B
2194D
392
318D2
152
290B
923B
LEGEND
SCALE
146 ELLIOTT SILT LOAM
152 DRUMMER SILTY CLAY LOAM
232 ASHKUM SILTY CLAY LOAM
290B WARSAW SILT LOAM
298 BEECHER SILT LOAM
318D2 LORENZO LOAM
330 PEOTONE SILTY CLAY LOAM
343 KANE SILT LOAM
392 ORTHENTS COMPLEX LOAMY
442 MUNDELEIN SILT LOAM
531
531B MARKHAM SILT LOAM
531C2
533 URBAN LAND
534 ORTHENTS COMPLEX CLAYEY
536 DUMPS
923B MARKHAM ASHKUM COMPLEX
2194D MORLEY COMPLEX
LOCATION MAP
MCHENRY
LAKE
COOK
KANE
DUPAGE
LAKE ELLYN
WILL

or 12 percent of the area. Individual soil identification in this unit is not possible because 85 percent of the area is covered by buildings or pavement. The Morely complex (U194D) which accounts for 6 percent of the surface area occupies some 30 acres. This soil unit is formed in silty loam, glacial till on uplands. It is well drained, with a high erosion potential similar to Markham. The next soil unit of any significance is Lorenzo (318D2) which accounts for 3 percent of the soil cover or approximately 14 acres. This unit consists of shallow, well drained soils that are superimposed on sand and gravel in upland areas. The erosion potential of this soil is less than that of Morely but still is relatively high. The other units, accounting for approximately 3 percent of the remaining soil area, are Mundelein (442), Drummer (152) and Warsaw (290B). Excavated or filled material account for less than one percent of the soils in the basin.

All of the soil units have a very similar range of permeability, i.e. 0.63-2.00 inches per hour. These soils are also similar in their acidic nature with pH's in the range of 5.6 to 7.3. And the waterholding capacity of these soils is .0.2 inches per inch of soil. These and other characteristics are given in Table 2-2.

Vegetation

The predominant forms of vegetation in the watershed are grasses, decorative shrubs and bushes and mature trees.

Table 2-2: Characteristics of Soil Types

Soil Name/ Number	Representative Slope (Percent)	Area (Acres)	Percent	Hydrologic Soil Group	A Horizon Permeability (in/hr)	A Horizon Soil-Water pH	Water Capacity A,B, & C Horizons (in/in)
Markham-Ashkum-Urban #923B	2-4	403.0	.75	C	.63 - 2.00	5.6 - 6.5	.20
Urban Land #533	0-2	65.0	.12	-	-	-	-
Morley #U194D	7-12	30.0	.06	C	.63 - 2.00	5.6 - 6.5	
Lorenzo #318D2	7-12	14.0	.03	A	-	-	-
Mundelein #442	0-2	9.0	.01	B	.63 - 2.00	6.1 - 7.3	.20
Cut and Fill #392	0-2	6.0	.01	-	-	-	-
Drummer #152	0-2	5.0	.01	B	.63 - 2.00	6.6 - 7.3	.20
Warsaw #290B	2-4	2.0	0	B	.63 - 2.00	5.6 - 7.3	.20
Average		534.0		C	.63 - 2.00	5.6 - 7.3	.20

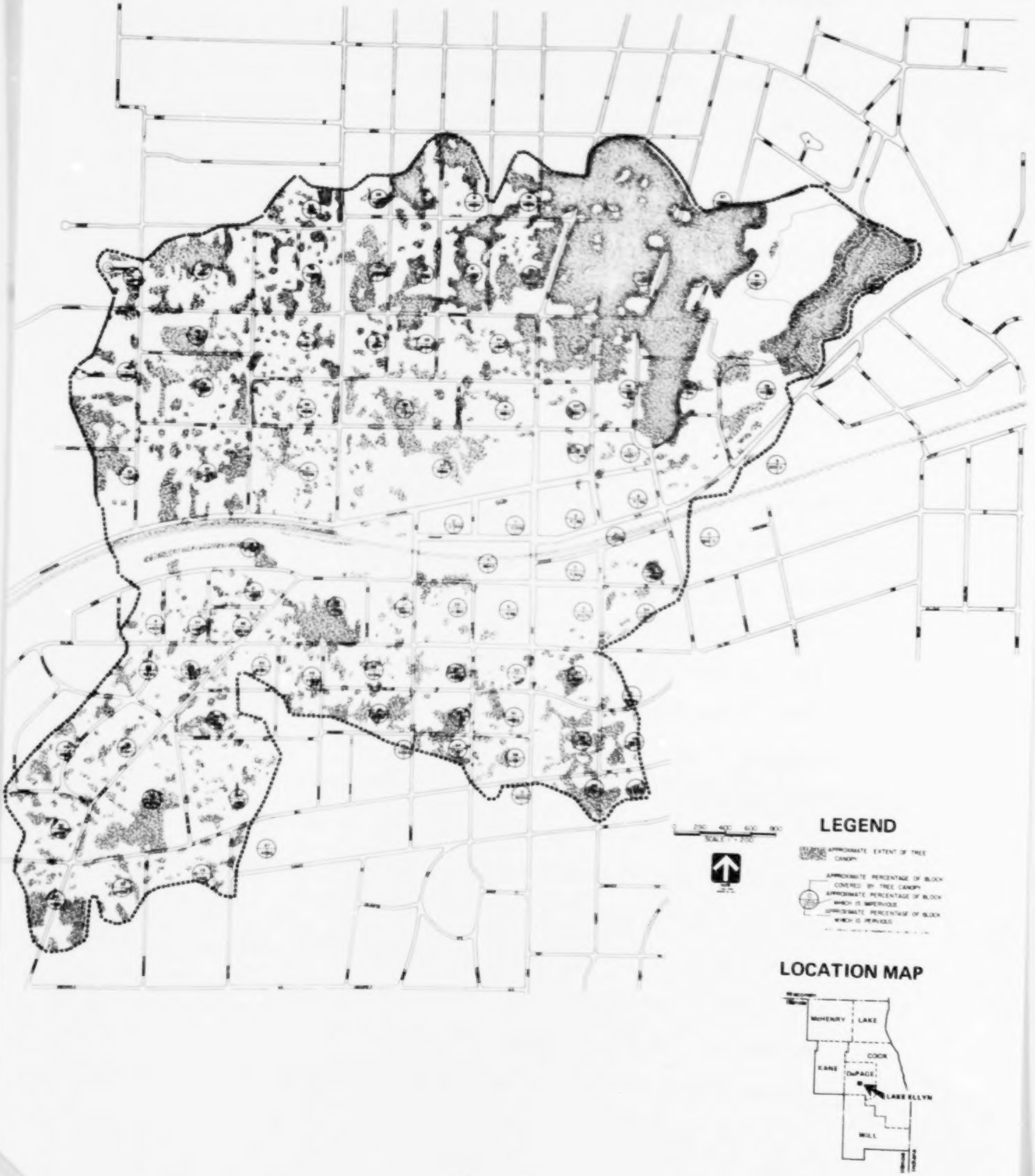
Eighty five percent of the pervious surface is covered by perennial, lawn grasses with shrubs and bushes covering the remaining area. The tree canopy (see Figure 2-3) overlies these areas including impervious areas and covers approximately one-third of the watershed. The vegetative cover is similar to suburban developments in this climatic region.

Demography

The watershed is wholly within the administrative jurisdiction of the Village of Glen Ellyn except for the park surrounding Lake Ellyn which is owned by the Glen Ellyn Park District. After a railroad line was completed in 1850, linking the area with Chicago, Lake Ellyn became a popular summer resort and permanent development started around the lake in 1900 -- by 1910, most of this development had been completed. The development of Glen Ellyn has continued up to the present, but most of this in recent years outside the watershed.

The population of Glen Ellyn according to the 1980 census is 23,649; of this population, approximately 4,170 people live in the watershed. Dividing the resident population by the drainage area yields a population density of approximately 5,000 persons per square mile. While the majority of people in Glen Ellyn earn their living in Chicago, there are light industrial establishments in the Village and, in the central portion of the watershed, a commercial area thrives.

FIGURE 2-3: TREE CANOPY


0 200 400 600 800
SCALE 1" = 200'
LEGEND
APPROXIMATE EXTENT OF TREE CANOPY
APPROXIMATE PERCENTAGE OF BLOCK COVERED BY TREE CANOPY
APPROXIMATE PERCENTAGE OF BLOCK WHICH IS IMPERVIOUS
APPROXIMATE PERCENTAGE OF BLOCK WHICH IS PERVIOUS
LOCATION MAP
McHENRY
LAKE
COOK
KANE
DuPAGE
LAKE ELLYN
WILL

Eighty percent of the land use is low-density single family residential. Commercial, institutional and recreational land uses each account for 5 percent. High-density residential accounts for 3 percent and 2 percent of the land use is water or wetlands. As mentioned previously, undeveloped land does not exist in the watershed (see Figure 2-4).

The watershed is crisscrossed by 18 miles of road. In large, these roads are laid out on a grid pattern running generally north-south and east-west. One notable exception to this is the main road through the commercial section, Pennsylvania Avenue, which parallels the commuter railroad line (see Figure 2-5). Ninety eight percent of the streets have curbs and gutters with only 2 percent being drained by swales. Ninety four percent of the streets are covered with asphalt and only 6 percent with concrete (see Table 2-3). Of the 56 acres of streets in the watershed, 77 percent are rated to be in fair condition meaning that the decomposition of the street surface is slight, 18 percent of the streets are considered to be in good condition with the decomposition minimal. Less than 5 percent of the streets are rated as poor with decomposition readily apparent.

The high traffic streets run through the commercial area and account for 13 percent of the street area. Thirty nine percent of the street area has medium traffic densities and 47 percent of the street area has low traffic densities (see

FIGURE 2-4: LAND USE

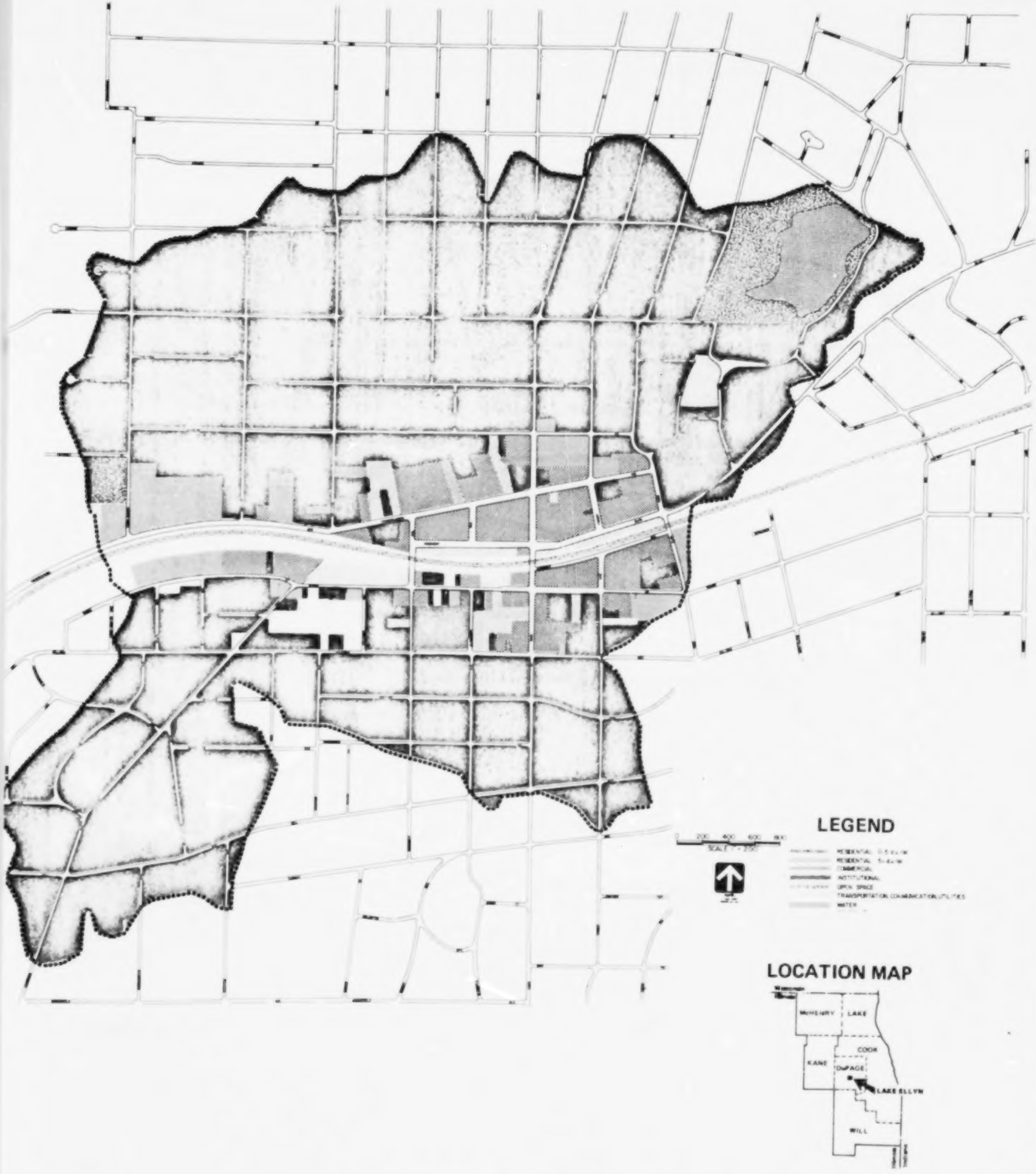

LEGEND
0 200 400 600 800
SCALE 1" = 200'
RESIDENTIAL
RESIDENTIAL
COMMERCIAL
INSTITUTIONAL
OPEN SPACE
TRANSPORTATION COMMUNICATION/UTILITIES
WATER
LOCATION MAP
McHENRY
LAKE
COOK
KANE
DuPAGE
LAKE ELLYN
WILL

FIGURE 2-5: TRAFFIC DENSITIES

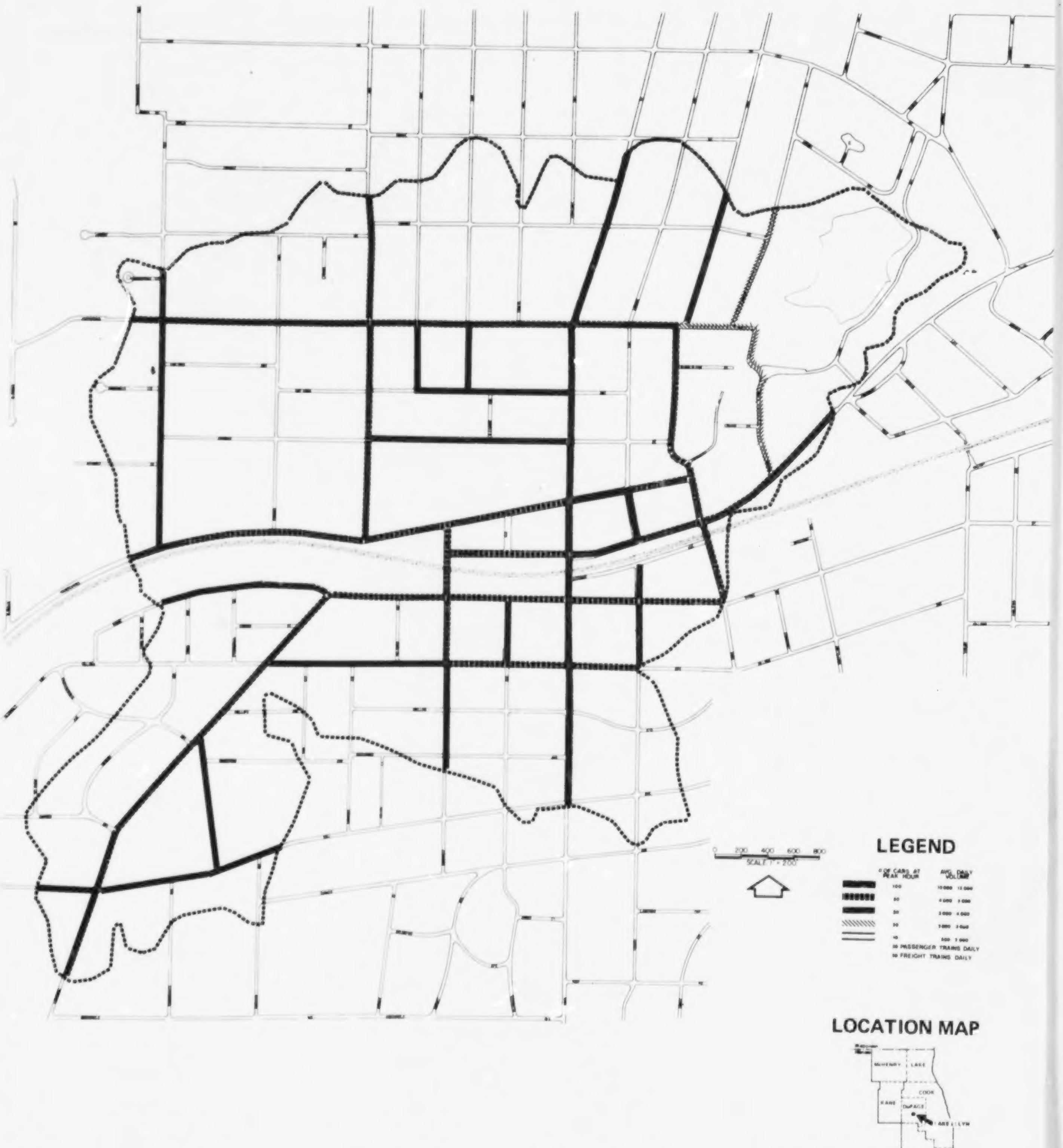

0 200 400 600 800
SCALE 1" = 200'
LEGEND
# OF CARS AT PEAK HOUR
AVG. DAILY VOLUME
100
10 000 12 000
10
PASSENGER TRAINS DAILY
FREIGHT TRAINS DAILY
LOCATION MAP
McHENRY
LAKE
COOK
KANE
DuPAGE
WILL

Table 2-3: Street Conditions and Paving Materials

Street Type and Condition	Acres	Percent of Total
Asphalt:		
Good Condition	9.52	17.0
Fair Condition	41.8	74.5
Poor Condition	1.12	2.0
Total	52.4	93.5
Concrete:		
Good Condition	0.42	0.7
Fair Condition	1.55	2.8
Poor Condition	1.66	3.0
Total	3.63	6.5
Grand Total	56.0	100.0

Driveway Material	Acres	Percent
Asphalt/Blacktop	10.9	50.4
Concrete	6.55	30.2
Gravel/Dirt	4.00	18.5
Grass	0.15	0.7
Brick	0.05	0.2
Total	21.68	100.0

Table 2-4). Figure 2-5 shows the distribution of traffic by range of daily volumes and Table 2-5 relates traffic volumes to miles of street. The mean daily traffic volume in and through Lake Ellyn is estimated to be 2,660 vehicles.

Impervious Areas

Besides streets and roads, there are four other classes of impervious surfaces: parking areas, driveways, sidewalks, and roofs. The total impervious area in the basin is 184 acres. Of this, 96 acres, or 30 percent of the area as previously reported, is in streets and roads. Parking lots account for 14 percent and driveways and sidewalks for 12 percent. Roofs, the largest single class of imperviousness, account for 43 percent of the impervious area. In turn, the impervious area account for 34 percent of the total watershed (see Table 2-4). Fortunately, not all of this impervious area is hydraulically connected (i.e. it is considered unconnected if runoff from an impervious area first passes over a pervious surface before reaching the sewer). In fact, only 83.1 acres of the total impervious area are hydraulically connected. This results in the hydraulically connected area representing 45 percent of the impervious area and the unconnected area representing 55 percent. Relative to the total watershed, the fraction of hydraulically connected impervious area is 16 percent.

The pervious component of the watershed is comprised of lawns, parkways and parks. These areas, as previously men-

Table 2-4: Land Cover Distribution

Category	Watershed	Total Area	Traffic	Land Use	Hydraulically Connected	Not Hydraulically Connected
1. Streets	Main	42.8	High	-	6.0	0
			Medium	-	19.9	0
			Low	-	16.9	0
	Linden	13.2	High	-	1.5	0
			Medium	-	2.1	0
			Low	-	9.6	0
	Total	56.0				
2. Parking Area	Main	24.7			9.9	14.8
	Linden	1.3			0.5	0.8
	Total	26.0				
3. Driveways & Sidewalks	Main	17.4			1.8	15.6
	Linden	4.3			0.4	3.9
	Total	21.7				
4. Roof Area	Main	68.5		Commercial	11.6	11.9
				Residential	2.3	42.7
	Linden	11.0		Commercial	0	0
				Residential	0.6	10.4
	Total	79.5				
5. Total Impervious Area	Main	153.4			68.4	85.0
	Linden	30.6			14.7	15.9
	Total	184.0			83.1	100.
6. Surface Area	Main	390				
	Linden	95				
	Other	49				
	Total	534				

Table 2-5: Traffic Volume Distribution

Average Daily Vehicle traffic Volume	Miles of Street	Percent (%)
10,000-15,000	1.12	6.2
2,000- 5,000	7.27	40.4
500- 2,000	9.61	53.4
Total	18.00	100.0

tioned, are generally covered with grass, under an umbrella of tree canopy. Given the low percentage of swale drainage in the watershed, surface runoff from pervious areas generally travels over an impervious surface, such as a driveway or sidewalk, before reaching the storm drainage system.

The storm sewer system is laid out in a converging tree pattern; there are very few loops in the pipe network except at the lower end of the main watershed. The laterals or first-order links of the system are generally made of clay or concrete with diameters ranging from 8 to 12 inches. The pipe size, of course, increases in the direction of flow and terminates at Lake Ellyn. The outlet sewer of the main drainage basin is a box culvert measuring 4.5 feet by 5 feet. This storm sewer was augmented during the course of the study by a 60 inch pipe. The new sewer runs from the lake approximately 1,200 feet southwest to connect into the main drainage network. The outlet of the Linden basin is an 18 inch pipe, and the pipe diameters of the small drainage areas on the southeast edge of the lake are all 12 inches.

The sewer system in the watershed appears to be generally well maintained. Inspection of the sewers by means of the manholes, reveal little or no deposition. Starting at Lake Ellyn, the old trunk sewer could be traversed for approximately 1,200 feet. Even given the reasonably flat grade of this sewer (0.0017 feet/foot in the last 500 feet), no significant deposits were ever observed on the invert.

Also, there appeared to be no significant cross-connections between the sanitary and storm sewer system.

En route to Lake Ellyn, stormwater runoff leaves the pervious and impervious surfaces and then enters one of 364 catch basins prior to reaching the storm sewer. Of the total number, some 320 catch basins are in the Main Watershed. Based on a sampling of these catch basins, the mean diameter is 32 inches and the depth approximately 27 inches. This provides, on the average, 12.5 cubic feet of sediment and liquid storage per catch basin or 4,550 cubic feet for the entire watershed. The catch basins are routinely cleaned by the Public Works Department on an annual basis and sludge deposits rarely exceeded one-fifth of the basin's capacity. All the catch basins appeared to be in good repair.

CHAPTER 3: LAKE ELLYN

History

Lake Ellyn is nearly as old as Glen Ellyn itself. The lake was constructed for $1,300 in 1889 by placing an earthen dam across a tributary to the East Branch of the DuPage River. The lake was originally constructed to promote tourism for the area. Glen Ellyn already boasted five naturally-flowing springs in the kames immediately east of the lake and another mineral spring one-quarter mile southwest of the lake. The construction of the Glen Ellyn Hotel completed the resort and Lake Ellyn became a popular weekend retreat for Chicago area residents.

Although springs were present in the immediate area, Lake Ellyn was supplied, then as now, entirely by surface and subsurface runoff. Before the construction of sewers in 1914, raw domestic wastes from the developed urban area were sometimes transported to the lake by stormwater. Lake water was turbid even then, especially at the southern end of the lake (Cowan, 1981). The south end of the lake was filled in 1922 to build playing fields for the Glenbard West High School. The lake has been dredged four times since its construction. The most recent dredging was completed along with other work in 1970. This work involved dredging of sediments, reshaping of bottom contours, construction of an underwater barrier dam, and shoreline modification and stabilization. About 37,000 cubic yards of sediments were removed from the lake bottom during this project. The lake is currently surrounded by Lake Ellyn Park and Glenbard West High

School and is owned and managed by the Glen Ellyn Park District.

Physical Characteristics

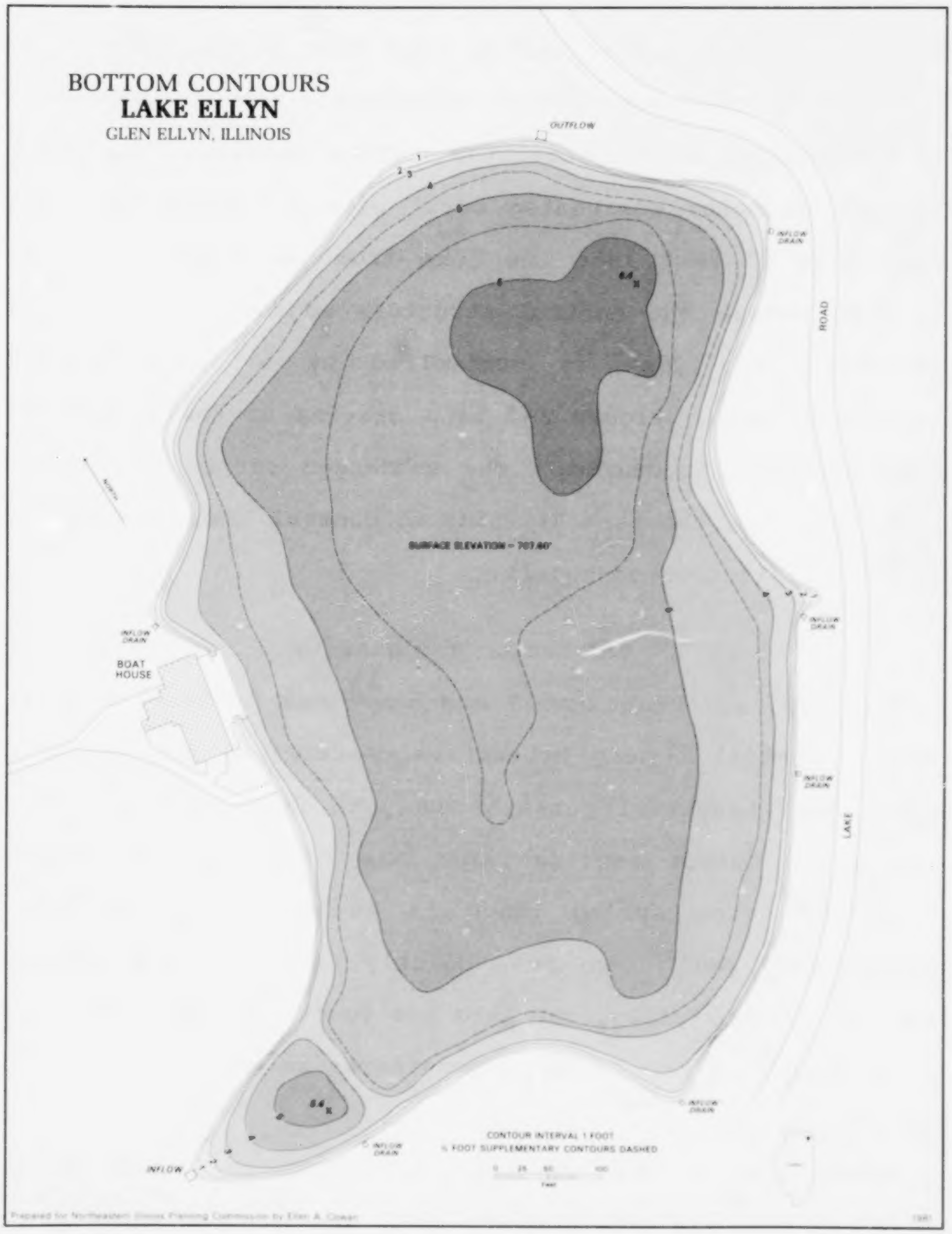
Figure 3-1 presents a bathymetric map of Lake Ellyn. At normal pool elevation of 707.60 the lake contains 44.8 acre feet of water. The surface area of the lake is 10.2 acres and its average depth is 5.0 feet with a maximum depth of 6.4 feet. The lake is surrounded by 2,950 feet of shoreline.

Lake Ellyn is divided into two sections by a pervious, ten-foot wide underwater dam across the bay to which the main inlet discharges. The purpose of this dam was to decrease inlet flow velocities and thereby promote settling of suspended material over a smaller, more easily dredged area. The dam also serves to prevent resuspension of settled material. The barrier dam, being about 170 feet from the inlet and submerged, has little or no backwater effect on incoming stormwater. The basin created by this dam has a maximum depth of 5.4 feet.

Inlets/Outlets

Prior to 1980, 73 percent of the lake's watershed drained to Lake Ellyn via a 4.5 foot by 5.0 foot box culvert. In the fall of 1980, a relief storm sewer was laid parallel and immediately adjacent to the existing box culvert. This new relief culvert is 5.0 feet in diameter and does not drain any new area to the lake but merely acts to relieve an upstream constriction. An 18-inch inlet near the boat house drains another sub-watershed accounting for 18 percent of the area tributary to the lake. The other nine

FIGURE 3-1: LAKE ELLYN BATHYMETRIC MAP


BOTTOM CONTOURS
LAKE ELLYN
GLEN ELLYN, ILLINOIS
OUTFLOW
INFLOW DRAIN
INFLOW DRAIN
BOAT HOUSE
INFLOW DRAIN
INFLOW DRAIN
INFLOW DRAIN
INFLOW DRAIN
INFLOW
NORTH
ROAD
LAKE
SURFACE ELEVATION = 707.60'
6.4
6.4
CONTOUR INTERVAL 1 FOOT
½ FOOT SUPPLEMENTARY CONTOURS DASHED
0 25 50 100
Feet
Prepared for Northeastern Illinois Planning Commission by Ellen A. Cowan
1981

percent of area tributary to the lake drains via the remaining five minor inlets or via surface runoff (see Figure 3-1).

There are two outlets leading from Lake Ellyn, both of which are housed in the same control structure. One of these outlets is a rectangular weir controlling surface outflow. The other is a 30-inch diameter corrugated metal pipe submerged at the lake bottom some 40 feet into the lake from the control structure. This pipe enters the control structure adjacent to the surface weir where its flow is controlled by a fully adjustable rectangular weir. Figure 3-2 is a drawing of the side-by-side, outlet control structures. The submerged outlet is adjustable enough to enable the park district to control lake levels for ice skating, maintenance or repair.

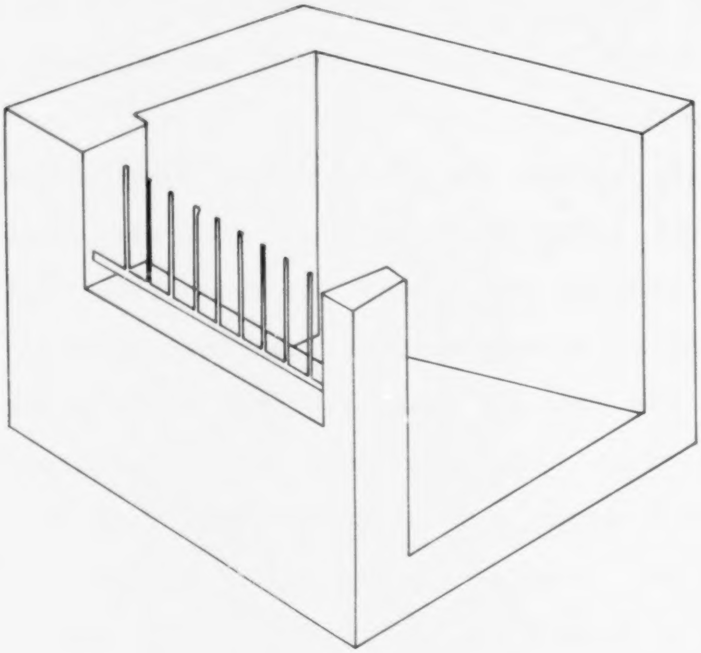
Aesthetics and Quality

Lake Ellyn, although turbid and sometimes burdened with algal blooms, is still a very attractive centerpiece for one of Glen Ellyn's most beautiful parks. The lake is ringed by expensive homes whose owners consider the lake to be a great amenity. Debris left from spring thaws is an occasional problem but usually the park district quickly removes any unsightly material. Historically, the lake has functioned as a focal point for the community and is still considered as such.

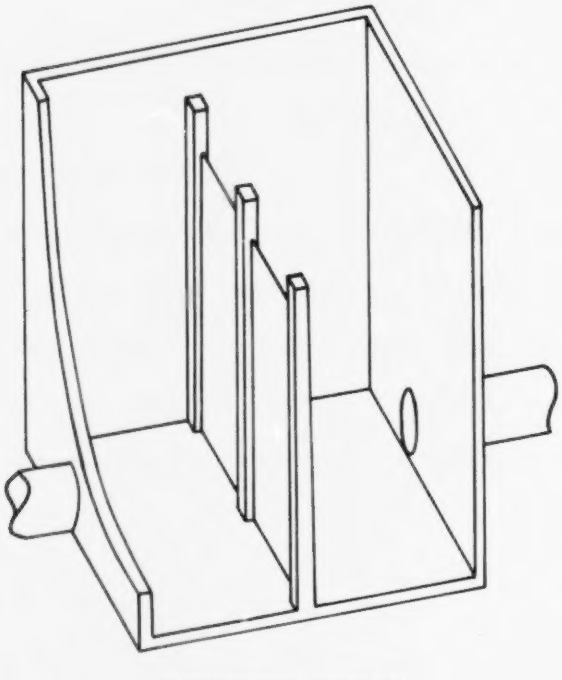
Water Column

A comparison of the results of studies performed in 1969, before the lake was modified, in 1974, and in this study indicate

FIGURE 3-2: LAKE ELLYN OUTLET STRUCTURES



SURFACE OUTLET



SUBMERGED OUTLET

the wide variability in lake quality during the summer (see Table 3-1). Table 3-2 presents water column quality as measured in this study.

Chloride values are much higher than would be expected for unpolluted lakes. Given that chloride concentrations in the shallow groundwater around the Lake Ellyn watershed have been increased by street salting from less than 10 mg/l to over 150 mg/l in the last 30 years (Zeizel, 1962; Sasman, 1981), impacts on Lake Ellyn are inevitable. Chloride levels are highest in winter and spring when salt is washed from streets. Lake levels at this time are about 170 mg/l. Chloride levels are lowest during the summer when most street salt has already been washed off and stormwater runoff has flushed the lake. Chloride levels rise again in the fall, reflecting draining of shallow groundwater to the lake by storm sewers.

Phosphate levels are high enough to support algal blooms as they apparently have been for at least the last 13 years, although they are similar to levels in other northeastern Illinois lakes (Kothandaraman, 1977; Kothandaraman, 1979).

Suspended solids concentrations are about what would be expected from the effluent of a well run secondary wastewater treatment facility. Total solids in the water column have changed very little in the last eight years.

Table 3-1: Historical Water Column Quality

Constituent	Harza August, 1969	Rhodes[1] August, 1974	This Study[2] August, 1980
Ph	6.9	8.7	9.35
TSS	40.0	29.0	16.0
TDS	-	338.0	308.0
Chlorides	40.0	73.0	63.3
Alkalinity	100.0	134.0	109.0
NH_3	0.01	-	0.30
NO_2+NO_3	-	0.043	0.07
Ortho PO_4	0.03	0.27	0.03
Total PO_4	0.06	0.67	0.22

[1] measurement @ 1 m

[2] mean noon depth-integrated measurements

Table 3-2: Lake Ellyn Water Column Constituent Concentrations (mg/l)

Constituent	Summer	Fall	Spring
TSS	16.4	26.8	20.0
TDS	355	396	313
Cl	46.9	69.0	170
COD	44.7	35.0	28.1
NH_4	0.68	0.24	0.19
Dissolved NH_3	0.45	0.07	0.10
NO_2NO_3	---	---	---
Dissolved NO_2NO_3	0.21	0.08	0.11
Total PO_4	0.24	0.19	0.05
Dissolved PO_4	0.06	0.02	0.02
Cu	0.010	0.008	0.007
Dissolved Cu	0.010	0.006	0.005
Pb	< 0.11	< 0.11	0.042
Dissolved Pb	< 0.11	< 0.11	0.040
Zn	0.038	0.015	0.027
Dissolved Zn	0.033	0.015	0.015

Lake Ellyn appears to exhibit some temperature stratification with depth during the summer months but this is a temporary phenomenon due to radiant heating and quiescent conditions. During fall and spring, the lake is typically isothermal (see Figure 3-3).

During quiescent summer periods, dissolved oxygen near the lake bottom can become depleted (see Figure 3-4). This is the result of decreased reaeration due to low wind velocity. When this occurs, sediment oxygen demand of the high volatile solids of lake bottom material (14 percent) and water column BOD_5 (20 ppm) are sufficient to deplete available oxygen.

The low bottom dissolved oxygen may well limit benthic populations and inhibit fish reproduction. It appears that for the most part, however, lake bottom dissolved oxygen remains above 6 ppm based on other sampling efforts (see Figure 3-4).

Unionized ammonia concentrations in the lake may cause stress to organisms in the summer months. During this season algal blooms can remove carbon dioxide from the water column causing pH to rise and accentuating this problem since as pH rises more ammonia is present in the unionized form. pH values in excess of nine, ammonia values of 0.68 ppm, and temperature of 25°C were noted at the two foot level (Hill, 1981). However, at lower depths conditions are less stressful offering a haven for aquatic organisms.

None of the metals concentrations in Lake Ellyn exceed the general water quality criteria for Illinois waters (this, even

FIGURE 3-3: LAKE TEMPERATURE VERSUS DEPTH

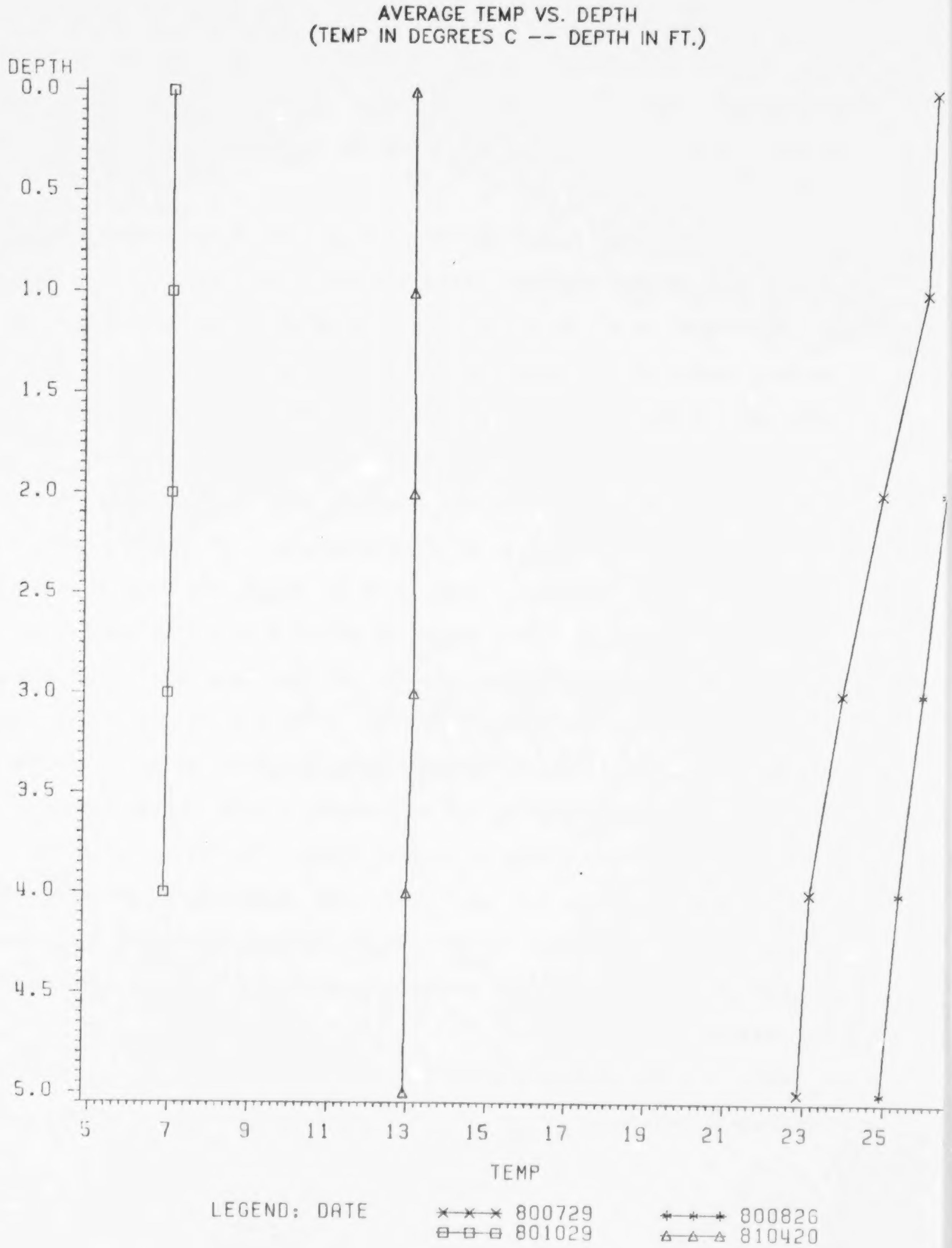
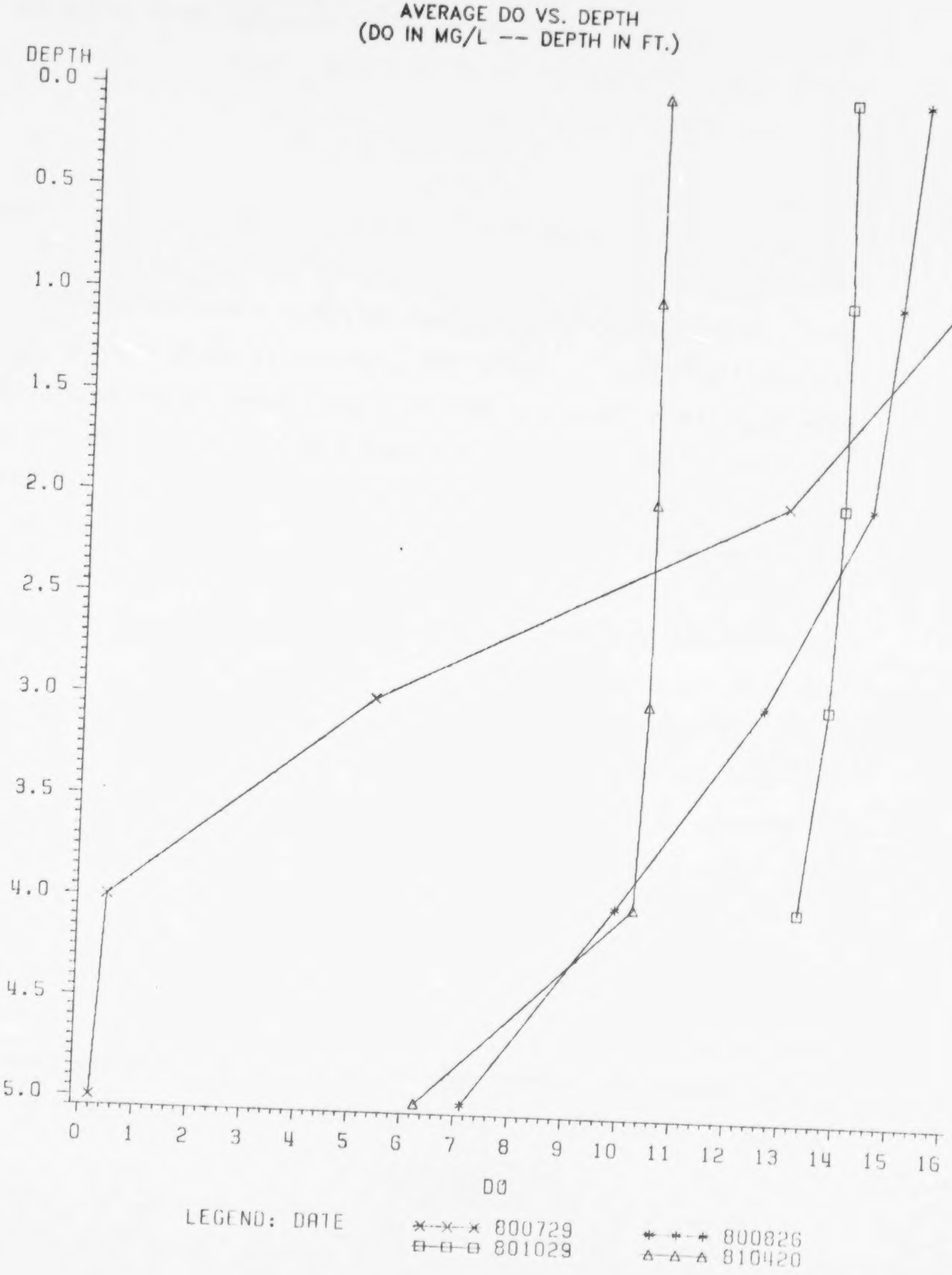


FIGURE 3-4: LAKE DISSOLVED OXYGEN VERSUS DEPTH



though the runoff to the lake routinely violates these criteria). Metals concentrations in Lake Ellyn are similar to those found for other Illinois lakes (Hullinger, 1975).

Sediment

Lake Ellyn retains about 125 tons of solids every year in the form of sediment. This sediment occupies a volume of 2,320 cubic feet. Based on this study, total sediment volume in the lake is 207,000 cubic feet. Figure 3-5 presents sediment depths. The lake supports a large population of phytoplankton and periphyton resulting in the deposition of dead vegetal matter. The decomposition of stormwater and algal materials results in a sediment oxygen demand of 3 grams per square meter per day at water temperature of 20°C. This oxygen demand is a significant factor in the depletion of water column oxygen when reaeration is absent as previously noted.

The sediment in Lake Ellyn is highly contaminated by constituents sorbed onto sediment surfaces (see Table 3-3). A comparison of sediment constituent concentrations in Lake Ellyn with those in 63 other Illinois lakes during the summer of 1979 is presented in Table 3-4 (Kelly, 1981). Based on a comparison of Lake Ellyn sediment with these values, it is apparent that the bottom material exhibits elevated to highly elevated constituent concentrations.

The impact of these sediment constituent concentrations is difficult to ascertain. Normally, they are sorbed onto soil

FIGURE 3-5: SEDIMENT DEPTHS

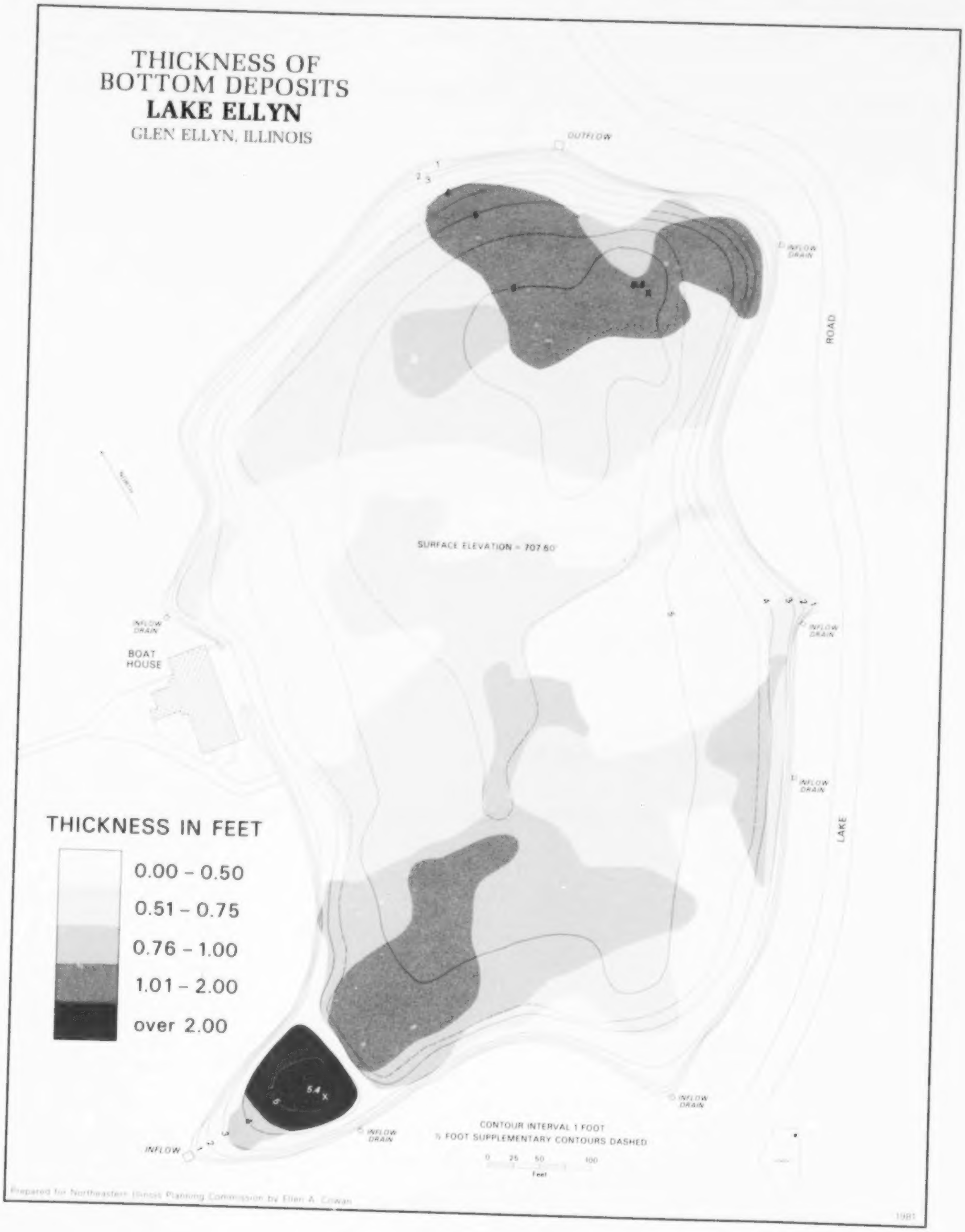

THICKNESS OF
BOTTOM DEPOSITS
LAKE ELLYN
GLEN ELLYN, ILLINOIS
OUTFLOW
INFLOW DRAIN
ROAD
LAKE
NORTH
SURFACE ELEVATION = 707.60'
6.6 x
5.4 x
BOAT HOUSE
INFLOW
THICKNESS IN FEET
0.00 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 2.00
over 2.00
CONTOUR INTERVAL 1 FOOT
½ FOOT SUPPLEMENTARY CONTOURS DASHED
0 25 50 100
Feet
Prepared for Northeastern Illinois Planning Commission by Ellen A. Cowan
1981

Table 3-3: Lake Ellyn Bottom Sediment Constituent Concentrations (ppm)

Constituent	Concentration Total
Percent Mass < 4u	14.5
Percent Mass < 63u	86.7
Percent Mass > 63u	13.3
COD	38,200
SOD @20°c	2.99
PO_4	2,200
NH_3	988
NO_2NO_3	3,560
Cl	---
Cu	144
Pb	1,130
Zn	580
Percent Volatile Solids	14.2

Table 3-4: Relative Sediment Quality

Constituent	Lake Ellyn	Normal	Elevated	Highly Elevated
Volatile Solids (%)	16.9	5-13	13-17	17
PO_4	2200	225-1175	1175-1650	1650
COD	38200	32500-162000	162000-226500	226500
Cu	144	100	100-150	150
Pb	1130	15-100	100-150	150
Zn	580	50-175	175-250	250

articles and are not available for interaction with lake organisms or the water column. However, the release or mobilization of metals and other pollutants from aquatic sediments is dependent on the physical, chemical and biological characteristics of the sediment and the surrounding water. Among the chemical characteristics of the water which are of concern is the presence of complexing agents. (Allen, 1981). In the autumn the input of humic and fulvic acids from decaying leaves could result in mobilization of metals from sediments or could act to inhibit the sorption of metals to sediments. Salt from road deicing and other sources can cause the mobilization of heavy metals which form strong chloro complexes. It has been shown that increased chloride reduces the adsorption of cadmium and zinc onto suspended particulate matter (Solomons, 1980). It has also been shown that salt runoff can result in the release of mercury from contaminated sediments (Feich, 1972). It has been observed in this study that higher concentrations of lead were observed with high chloride concentrations.

The most important factors of solution chemistry relating to metal sorption and desorption are pH and dissolved oxygen. Lowering the pH greatly affects the sorption of metals. Consequently, seasonal lowering of pH due to decreased algal activity, for example, may result in metal mobilization. Microbial depletion of dissolved oxygen in sediment or in the hypolimnion of a thermally stratified lake, such as can happen in Lake Ellyn, can result in the release of metals. With respect to dissolved metals concentrations in the lake and in effluent from such processes has been noted, except perhaps, for DPb. The potential for such interactions in the form of humic acid, chloride, and low water column dissolved oxygen are certainly present.

Priority Pollutants

Sediment from Lake Ellyn was examined in two ways for priority pollutants. The first way involved examination of a total sediment sample for each of the 129 constituents on the U.S. Environmental Protection Agency's priority pollutant list. Only 13 of the base/neutral compounds were identified and 12 of these were not herbicides or pesticides but were polynuclear aromatic hydrocarbons. The thirteenth was a phthalate ester. (See Table 3-5). Phthalate esters are associated with plastics, especially polyvinyl chloride and can be detrimental to aquatic organisms at low concentrations in the water column. The U.S. Environmental Protection Agency's criterion is 3 ug/l for freshwater aquatic life. This constituent is sorbed onto sediment and does not at present appear to be mobile to the water column.

The sediment was also examined to determine if it qualified as a toxic waste under the EP toxicity test specified in 40 CFR Part 261 (see Table 3-6). Tests were negative for all constituents considered.

Stormwater influent to Lake Ellyn may contain DDD, DDE, DDT, dieldrin, phenols, silvex, and 2,4-D based on 1980 U.S.

Table 3-5: Priority Pollutants in Lake Sediment

Pollutant	Concentration (ppb)
acenapthene	540
fluoranthene	3700
bis (2 - ethylhexyl) phtalate	690
benzo (a) anthracene	3800
benzo (a) pyrene	12000
benzo (k) fluorathene	1400
chrysene	3400
anthracene	1300
flourene	580
phenanthrene	2800
dibenzo (a,b) anthracene	4200
indeno (1, 2, 3-c, d) pyrene	15000
pyrene	3000

Table 3-6: EP Toxicity Test Results - Lake Sediment

Constituent	Lake Ellyn Sediment	Federal Standard
Arsenic	0.002	5.0 mg/l
Barium	0.64	100.0 mg/l
Cadmium	0.005	1.0 mg/l
Chromium, hex.	< 0.01	5.0 mg/l
Chromium, tot.	0.005	
Lead	0.08	5.0 mg/l
Mercury	< 0.0001	0.2 mg/l
Selenium	< 0.001	1.0 mg/l
Silver	0.006	5.0 mg/l
Endrin	< 0.01	20 ppb
Lindane	< 0.01	400 ppb
Methoxychlor	< 0.1	10,000 ppb
Toxaphene	< 0.2	1500 ppb
2,4 D	5.53	10,000 ppb
2,4,5 TP Silvex	0.30	1,000 ppb

Geological Survey data. The DDD, DDE, DDT and dieldrin concentrations are higher than the U.S. Environmental Protection Agency's criteria. However, subsequent sampling and analyses in 1981 showed no presence of these chemicals. Outflow from the lake, more indicative of actual water column concentrations, showed traces of phenols, silvex, and 2, 4-D but not in amounts exceeding federal criteria. Trace amounts of polynuclear aromatic hydrocarbons were also present in Lake Ellyn outflow but not in amounts exceeding federal criteria.

Aquatic Organisms

Lake Ellyn algal growths were of bloom proportions during spring, summer and fall water column sampling periods. Most of these algae were blue-greens especially *Aphanizomenon flos-aguae* during spring and summer months. This species is considered to be an indicator of poor water quality. During the fall, the populations shifted to greens especially *Chlorella ellipsoidea*. Diatoms were observed only during spring sampling. Zooplankton counts identified *Chaoborus* and *Senecella calanoides* as the predominant species during July sampling, *Bosmina longirostris*, *Cyclops vernalis*, and *Daphnia parvula* in August, *Keratella cochearis* and *Daphnia pulex* in October, and *Diaptomus pallidus* and *Keratella volga* in April. Chlorophyll *a* values ranged from 22 to 52 mg per cubic meter during summer, fall, and spring.

A fish survey completed in June, 1980 for Lake Ellyn by the Illinois Department of Conservation found the fish species listed in Table 3-7.

Table 3-7: Fish Species in Lake Ellyn

Species	Size (inches)
Largemouth Bass	13.0 - 14.5
Bluegill	4.5 - 6.5
Green Sunfish	2.0 - 5.0
Black Bullhead	9.5
Goldfish	5.5 - 9.5
Carp	23.0

The report concluded that green sunfish and goldfish were competing more effectively for survival in the lake. Possible reasons for this were lack of cover for bass and bluegill and overpopulation of green sunfish and goldfish. The shallowness of the lake and its lack of protected areas, coupled with the large sediment load delivered to the lake makes maintenance of a desirable self-sustaining fish population unlikely regardless of pollutant concentrations.

Inventories of benthic macroinvertebrates living in Lake Ellyn sediment revealed that the predominant species are from *Chaoborus*, Chironomidae, and Tubificidae. *Chaoborus* are the most numerous in the area between the main inlet and the barrier dam, especially in the late fall and winter. Populations appear to peak in the fall and are at their nadir in late spring. Chironomidae are also numerous in this area especially in late winter. Populations in the main lake are about equally divided between *Chaoborus* and Chironomidae with the former most numerous in summer and early fall and the latter most numerous in late fall and late winter. *Chaoborus*, Chironomidae, and Tubificidae are all tolerant of low dissolved oxygen conditions and hence poor water quality.

Recreational Uses

One of Lake Ellyn's principal uses is stormwater detention but significant recreational uses of the lake occur. A 1969 report stated, "The lake and Lake Ellyn Park are extensively used as the focus of short family outings, walks, bike rides, etc. The lake also enjoys considerable use as a fishing pond, primarily by boys and girls under 16 who arrive on foot or by bicycle and are exempt from state fishing license requirements. Observations on several days in the summer of 1969 ranged from a minimum of two on up to 20 or more fishermen or girls at a time.

The lake also enjoys limited boating use. Private rowboats, canoes and very small sailboats are allowed under special permit from the Park District (Harza, 1969).

All of these uses were verified during the present study. Recreational running in the park adjacent to the lake is very popular. The Glenbard West athletic fields are also adjacent to the lake. Fishing is also still very popular with younger village residents. Perhaps, the most important recreational use of the lake is for ice skating. Lake Ellyn is one of the most popular ice skating areas in DuPage County and the Park District devotes virtually its entire staff to maintaining the lake for this purpose during the winter.

CHAPTER 4: HYDROLOGY

Climate

Northeastern Illinois is classified climatically as "humid continental." Precipitation averages about 37 inches a year with April, June and July being the months of greatest precipitation (see Table 4-1). Approximately 35 inches of snow falls each year, from late December through February. The mean annual temperature is 49 degrees Fahrenheit (see Table 4-2) with the warmest month being July. The prevailing winds are from the southwest (this places the study area upwind from the industrialized sections of the region). Skies are clear or partly cloudy for an average of 197 days per year. Wind movement, air temperature and solar radiation combine to produce a potential evaporation, 33 inches per year (see Table 4-3) which is approximately equivalent to the annual precipitation; however, net evaporation is two thirds of the potential (Hydrocomp, 1976).

Precipitation

Precipitation is one of the more important considerations in characterizing urban stormwater runoff. Not only does precipitation carry with it impurities absorbed from the atmosphere, but it initiates the runoff process and provides the transport medium for waste materials. The frequency, intensity and duration of stormwater runoff are

Table 4-1: Precipitation (inches) -- Wheaton, Illinois (1964-74)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
$\bar{x}$	1.78	1.16	2.41	4.34	3.78	4.38	3.78	3.72	3.94	2.44	2.47	2.80
s.d.	1.07	0.66	0.98	1.55	1.80	1.70	1.42	2.99	1.91	1.79	0.93	1.24
Max	4.01	2.38	4.22	5.84	6.67	7.18	6.66	10.7	7.30	6.47	4.26	5.79
Min	0.71	0.18	1.21	0.68	1.36	2.29	2.36	1.25	0.72	0.16	1.43	1.44

	Annual
$\bar{x}$	37.00
s.d.	5.51
Max	48.1
Min	28.00

Table 4-2: Temperature ^{o}F -- O'Hare Airport (1964-74)

	Jan[1]		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
$\overline{x}$	30	14	34	18	45	28	59	39	69	47	79	58	83	62	81	61	74	54	64	43	48	32	36	22
s.d.	4	5	2	4	5	4	3	3	5	3	3	3	2	3	2	4	2	4	3	5	3	1	4	4
Max	36	21	36	24	53	36	63	43	75	52	85	62	87	66	84	66	79	60	71	52	53	34	43	28
Min	24	7	29	11	34	20	54	35	64	42	74	53	79	57	77	55	72	49	58	34	42	30	30	16

	Annual	
$\overline{x}$	58	40
s.d.	1	2
Max	61	43
Min	56	37

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[1] First column is the monthly average maximum daily temperature, second column is the monthly average minimum daily temperature.

Table 4-3: Evaporation (inches) -- O'Hare Airport (1964-74)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
$\overline{x}$	0.77	1.05	1.90	3.09	4.34	4.88	5.16	4.60	3.15	2.49	1.28	0.70
s.d.	0.21	0.21	0.43	0.60	0.68	0.49	0.54	0.78	0.41	0.36	0.28	0.22
Max	1.10	1.31	2.67	4.30	5.07	5.92	6.00	5.79	3.74	3.04	1.90	1.17
Min	0.47	0.80	1.06	2.45	3.09	4.06	4.44	3.40	2.29	1.69	0.74	0.35

	Annual
$\overline{x}$	33.4
s.d.	2.67
Max	38.7
Min	30.0

related to those same characteristics of precipitation, although not directly due to the intervening influence of antecedent conditions. Nevertheless, the more urbanization, that is to say the more impervious area, the more directly the two sets of characteristics are linked. Consequently, it is important to consider the precipitation characteristics of the region when evaluating urban stormwater runoff or in designing urban stormwater controls.

The precipitation regime in northeastern Illinois and for the study watershed can be divided into two seasons: winter and summer. Whether snow or rain, precipitation in the winter is characterized by general frontal storms which generally are uniformly distributed over the region. On the other hand, the summer regime is characterized by intense, short duration, small diameter storms which inundate some areas and leave others dry. More so than with the winter storms, the summer storms originate in the southwest and traverse the region in a northeasterly direction. The less frequent, more extreme precipitation events range from the one-year recurrence interval of 0.85 inches in a 30-minute period (the approximate time of concentration of the Glen Ellyn watershed) to 2.15 inches for the 50-year event (see Table 4-4).

Based on the observations of stormwater runoff at Lake Ellyn, the storm intensity bears little relation to the concentration of constituents or load delivered to the

Table 4-4: Characteristics of Extreme Precipitation Events (30 minute storms)[1]

Recurrence Interval (year)	Inches
1	0.85
2	1.05
5	1.30
10	1.45
25	1.80
50	2.15

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[1] Huff, Floyd A., and John L. Vogel, Hydrometeorology of Heavy Rainstorms in Chicago and Northeastern Illinois, Phase I-Historical Studies, Illinois State Water Survey, Urbana, Illinois, 1976.

lake. The significance of storm intensity lies rather with the concern that the control strategy may be bypassed or not provide sufficient detention time to adequately treat the load delivered. The degree to which these events can be accommodated is discussed in Chapter 6. The most exteme 30 minute event during the study period was 1.14 inches. This is equivalent to the mean annual 30 minute storm.

Based on 13 years of record from the O'Hare Station, operated by the U.S. Weather Bureau, there are 198 events per year (in this case an event is defined by one or more successive hours of precipitation with one or more dry hours preceding and following precipitation). However, 70 percent of these events do not cause runoff in that the precipitation does not exceed interception storage. For the Glen Ellyn watershed, the interception storage is 0.14 inches. Eliminating the events equal to or less than this amount of precipitation, reduces the annual total to 60 events, based on the 13-year record. Given this storm criteria, the mean event produces 0.5 inches of precipitation while 58 percent of the events are less than 0.4 inches (see Table 4-5). The mean event duration is 5.6 hours with 50 percent of the events lasting for less than 4 hours (see Table 4-6). The mean inter-storm duration, or dry period, is 140 hours with approximately 50 percent of the inter-storm period lasting for 84 hours or less (see Table 4-7).

As mentioned earlier, the precipitation characteristics during the study year (July 1, 1980 through June 30, 1981)

Table 4-5: Precipitation Statistics -- O'Hare (1964-77)

Total Hours = 113,976.00
Total Events = 779.00
Mean = 0.50
Variance = 0.19
Standard Deviation = 0.44

Interval	Cumulative Percent
0.01 to 0.10	0.0
0.11 to 0.20	21.1
0.21 to 0.30	44.0
0.31 to 0.40	58.2
0.41 to 0.50	66.1
0.51 to 0.60	72.4
0.61 to 0.70	79.5
0.71 to 0.80	83.8
0.81 to 0.90	87.0
0.91 to 1.00	90.1
1.01 to 3.80	100.0

Table 4-6: Precipitation Duration Statistics -- O'Hare (1964-77)

Total Hours	=	113,976.00
Total Events	=	779.00
Mean	=	5.61
Variance	=	19.10
Standard Deviation	=	4.37

Interval	Cumulative Percent
0.1 to 1.0	8.5
1.1 to 2.0	23.6
2.1 to 3.0	40.2
3.1 to 4.0	51.1
4.1 to 5.0	61.4
5.1 to 6.0	69.1
6.1 to 7.0	76.3
7.1 to 8.0	81.5
8.1 to 9.0	84.7
9.1 to 10.0	88.3
10.1 to 11.0	90.6
11.1 to 32.0	100.0

Table 4-7: Inter-Storm Duration Statistics -- O'Hare (1964-1977)

Total Hours = 113,976.00
Total Events = 780.00
Mean (Hours) = 140.52
Variance = 25,050.95
Standard Deviation = 158.27

Interval (Hours)	Cumulative Percent
0.1 to 12.0	20.1
12.1 to 24.0	28.2
24.1 to 36.0	33.5
36.1 to 48.0	37.4
48.1 to 60.0	41.7
60.1 to 72.0	45.4
72.1 to 84.0	49.1
84.1 to 96.0	52.1
96.1 to 108.0	55.3
108.1 to 120.0	57.4
120.1 to 132.0	61.5
132.1 to 144.0	64.4
144.1 to 156.0	66.2
156.1 to 168.0	68.1
168.1 to 180.0	70.6
180.1 to 192.0	72.3
192.1 to 204.0	73.5
204.1 to 216.0	75.4
216.1 to 228.0	76.9
228.1 to 240.0	79.0
240.1 to 252.0	80.3
252.1 to 264.0	81.9
264.1 to 276.0	82.9
276.1 to 288.0	83.8
288.1 to 300.0	85.1
300.1 to 312.0	86.2
312.1 to 324.0	87.2
324.1 to 336.0	88.8
336.1 to 348.0	90.4
348.1 to 936.0	100.0

are amazingly similar to the long-term averages. During the year, 65 events occurred which exceeded 0.14 inches. The mean event equals 0.54 inches with over half the events producing less than 0.4 inches of precipitation (see Table 4-8). The mean duration of storm is somewhat less, being 4.83 hours as opposed to 5.61 hours for the longer record, but again approximately 50 percent of the events were less than 4.0 hours in length as with the longer record. The mean inter-storm period was 128 hours which is only 8 percent shorter than the long-term mean. However, approximately 50 percent of the inter-storm periods were less than 84 hours, roughly equal to that of the long term characteristics.

Stormflow

Based on the statistics of runoff producing precipitation events, stormflow results once every 5 or 6 days. Approximately 70 percent of the surface runoff originates from hydraulically connected impervious surfaces. For the study year, the impervious yield was 34.3 inches. The pervious surface yielded 2.7 inches. Weighed by area and combined, the surface runoff yield of the Glen Ellyn watershed for the study period was 7.6 inches.

Flow and quality of runoff into and out of Lake Ellyn were monitored for the period April 1, 1980 through August 31, 1981. Using the resulting data, 98 separate events were recorded at the inlet and 84 at the outlet of the lake (see

Table 4-8: Precipitation Quantity Statistics -- Glen Ellyn

Total Hours = 8,748.00
Total Events = 65.00
Mean = 0.54
Variance = 0.20
Standard Deviation = 0.45

Interval	Cumulative Percent
0.01 to 0.10	0.0
0.11 to 0.20	12.3
0.21 to 0.30	38.5
0.31 to 0.40	52.3
0.41 to 0.50	67.7
0.51 to 0.60	76.9
0.61 to 0.70	76.9
0.71 to 0.80	80.0
0.81 to 0.90	83.1
0.91 to 1.00	86.2
1.01 to 1.10	86.2
1.11 to 1.20	92.3
1.21 to 2.30	100.0

Table 4-9: Precipitation Duration Statistics -- Glen Ellyn

Total Hours = 8,748.00
Total Events = 65.00
Mean = 4.83
Variance = 7.86
Standard Deviation = 2.80

Interval	Cumulative Percent
0.1 to 1.0	6.2
1.1 to 2.0	20.0
2.1 to 3.0	43.1
3.1 to 4.0	52.3
4.1 to 5.0	69.2
5.1 to 6.0	75.4
6.1 to 7.0	81.5
7.1 to 8.0	87.7
8.1 to 9.0	87.7
9.1 to 10.0	95.4
10.1 to 11.0	98.5
11.1 to 12.0	100.0

Table 4-10: Inter-Storm Duration Statistics -- Glen Ellyn

Total Hours = 8,748.00
Total Events = 66.00
Mean = 128.
Variance = 25,674.24
Standard Deviation = 160.00

Interval	Cumulative Percent
0.1 to 12.0	18.2
12.1 to 24.0	28.8
24.1 to 36.0	30.3
36.1 to 48.0	36.4
48.1 to 60.0	42.4
60.1 to 72.0	47.0
72.1 to 84.0	53.0
94.1 to 96.0	54.5
96.1 to 108.0	57.6
108.1 to 120.0	65.2
120.1 to 132.0	68.2
132.1 to 144.0	74.2
144.1 to 156.0	74.2
156.1 to 168.0	75.8
168.1 to 180.0	77.3
180.1 to 192.0	77.3
192.1 to 204.0	80.3
204.1 to 216.0	83.3
216.1 to 228.0	86.4
228.1 to 240.0	87.9
240.1 to 252.0	89.4
252.1 to 264.0	89.4
264.1 to 276.0	90.9
276.1 to 816.0	100.0

Tables 4-11 and 4-12). As is apparent from the recorded data, most storm events occurred in the spring and summer (the reported values in Tables 4-11 and 4-12 for spring and summer must be divided by two in that two sample sets are reported for these seasons) which, of course, reflects the precipitation characteristics. At the outlet, the maximum recorded flow rate was 45 cubic feet per second, recorded in the summer, while the maximum, volume was 33.1 acre feet, observed in the spring. Again, this is consistent with the climatic and precipitation characteristics of the region. During the spring, soil moisture is quite high and runoff per inch of rainfall much greater but the storms in this season are more evenly distributed and of lower intensity than in the summer resulting in lower peak discharges.

Attenuation of the storm hydrographs are readily apparent from the recorded data. For example, the maximum inflow rate of 135 cubic feet per second was reduced to 45 cubic feet per second at the outlet of the lake -- it should be noted that the outlet maximum rate also includes the inflow from the unmeasured areas such as the Linden Watershed. The effects of the additional drainage areas can be seen in the maximum outflow volume from the lake, 33.1 acre feet as opposed to the associated maximum inflow from the Main Watershed of 23.2 acre feet.

For the period of measurement, the mean number of days between storms was 5.23 which is approximately 0.6 days shorter than that for the associated precipitation events.

Table 4-11: Inlet Stormflow Statistics -- Main Watershed
(April 1, 1980 through August 31, 1981)

Statistics	Fall	Winter	Spring	Summmer	Total
Total Flow					
Total Volume (A-F)	66.42	55.69	333.01	205.59	660.71
Mean Flow (cfs)	0.36	0.31	0.92	0.67	0.64
Days	9	90	182	154	518
Stormflow					
Number of Events	12	2	46	38	98
Total Volume (A-F)	27.34	1.27	206.10	134.74	369.45
Maximum Rate (cfs)	33.0	8.80	169.0	134.0	169.0
Maximum Volume (A-F)	5.69	0.80	23.20	18.09	23.20
Mean Flow	4.79	1.04	7.50	8.75	7.45
Mean Volume (A-F)	2.28	0.64	4.48	3.55	3.77
Mean Duration (Hrs.)	5.75	7.42	7.23	4.91	6.12
Mean Intervening Dry Period (Days)	13.65	2.47	4.27	3.76	5.23
Baseflow					
Total Volume (A-F)	39.08	54.42	126.91	70.85	291.26
Mean Flow (cfs)	0.21	0.31	0.35	0.23	0.28
Days	92	90	182	154	518

Table 4-12: Combined Outlet Stormflow Statistics -- Total Watershed
(April 1, 1980 through August 31, 1981)

Statistics	Fall	Winter	Spring	Summer	Total
Total Flow					
Total Volume (A-F)	95.46	76.43	475.04	297.85	944.78
Mean Flow (cfs)	0.52	0.43	1.32	0.98	0.92
Days	92	90	182	154	518
Stormflow					
Number of Events	11	2	36	35	84
Total Volume (A-F)	41.95	1.92	301.27	200.84	545.98
Maximum Rate (cfs)	12.50	NR	38.00	45.00	45.00
Maximum Volume (A-F)	10.70	1.23	33.14	26.45	33.14
Mean Flow (cfs)	1.21	NR	2.90	2.66	2.53
Mean Volume (A-F)	3.81	0.96	8.37	5.74	6.50
Mean Duration (Hrs.)	37.98	NR	34.93	26.14	31.12
Mean Intervening Dry Period (Hrs.)	13.65	2.47	4.27	3.76	5.23
Baseflow					
Total Volume (A-F)	49.27	70.51	152.05	77.53	349.36
Mean Flow (cfs)	0.27	0.40	0.42	0.25	0.34
Days	92	90	182	154	518

This can be explained by the delay of water moving across the surface and through the storm drains which would tend to cause a longer duration for the runoff event and thereby shorten the intervening dry periods. Correspondingly, the mean duration of runoff event was approximately one hour greater than that of the associated precipitation event.

Baseflow

The baseflow component of the watershed's yield is approximately five inches per year. Baseflow, as measured and reported, originates from two principal sources: groundwater and leakage from the public water supply system. The leakage was estimated to be 0.10 cfs for a yield of one inch per year. Consequently, the groundwater intercepted by the sewers amounts to approximately four inches per year.

Water Budget

The water budget for the lake, both input and output, is given in Table 4-13. Besides the storm and baseflow entering and leaving the lake, there are two other components to the budget: precipitation and evaporation. Combined, these two components account for 10 percent of the water flux. On the input side of the budget, stormflow accounts for 57 percent, baseflow accounts for 38 percent and precipitation accounts for 5 percent. The total yield of the watershed for the study period was 12.7 inches. The spring season accounted for the greatest volume of water, 227 acre-feet, with summer close behind at 192 acre feet.

Table 4-13:--Water Budget (acre-feet)[a]

	Summer	Fall	Winter	Spring	Total	Percent
Input						
Stormflow	128	37.4	25.3	148	339	57
Baseflow	51.1	53.5	50.9	69.7	225	38
Precipitation	12.3	4.50	0.18	9.23	26.2	5
Total	192	95.4	76.4	227	591	
Output						
Evaporation	11.8	4.24	4.00	10.6	30.6	5
Stormflow	142	42.0	25.5	158	367	62
Baseflow	38.2	49.3	46.9	58.8	193	33
Total	192	95.5	76.4	227	591	
Percent	33	16	13	38	100	

[a] For study year

Winter produced the least, 76.4 acre-feet.

Since the outlet structures are not manipulated to retain water, there is no over season storage; therefore, the output budget is identical in terms of seasonal distribution to the input budget, at least in terms of total volume. Stormflow leaving the lake is greater than coming into the lake because of precipitation on the lake. Conversely, baseflow leaving the lake is less than inflow because of evaporation. The yield of the watershed as viewed from the outlet of the lake was 12.6 inches.

The water budget was constructed using the discharge measurements at the outlet of Lake Ellyn. Inflow to the lake from all watersheds, measured and unmeasured, was estimated using the outflow data. First, precipitation on the lake was subtracted from the inflow and evaporation was added to the outflow. The sum, then, was prorated over the entire watershed checking the stormflow and baseflow components with the measured data for the Main Watershed. The flow measurements for the Main Watershed were not directly used because of backwater interference and, after close scrutiny of the data, the outflow measurements appeared to be more reliable.

It was essential to construct the water budget in order to quantify the materials entering the lake and assess their seasonal significance. The relative importance of each of the flow components in the water budget will be addressed in Chapter 5.

CHAPTER 5: SOURCE AND CONTROL POINT SURVEYS AND MEASUREMENTS

Sources

Material contributions to the Lake Ellyn watershed can be divided into nine sources. These nine sources are the atmosphere, traffic, pavement decomposition, domestic chemicals, public works chemicals, animals, vegetation, soils, and the decomposition of construction materials.

Whatever their origin, these inputs must reach a control point; a point from which stormwater can transport them to the watershed's sewers and then to a receiving stream before they are of water pollution concern. Five control points have been identified in the Lake Ellyn watershed. These five control points are roofs, areas directly linked to sewers; areas not linked directly to sewers; catch basins; and Lake Ellyn. Areas not directly connected to storm sewers, either paved or unpaved, have been defined as "pervious areas." All areas directly connected to storm sewers have been defined as "impervious areas."

Materials budgets are focused on the chemical quality of source materials and their flux through control points on an annual basis. The general programs to monitor these sources and fluxes were discussed in Chapter 1. Details of these programs are given below.

Budgets were prepared for six constituents; total solids, chloride, phosphorus, copper, lead, and zinc. These six constituents were chosen because they are conservative i.e., they do not change form as readily as other constituents such as oxygen demand or nitrogen compounds, thereby enabling a mass balance to be formulated without considering chemical transformations. These constituents were considered to be representative of the general class of urban washoff contaminants. Similar budgets could be constructed for the other constituents for which data was collected.

Atmospheric Deposition

Atmospheric deposition data were collected weekly at two sites (Figure 1-3) through March, 1981. From March, 1981 through August, 1981 one site was operated with wet deposition collected every two weeks and dry deposition collected monthly. During weekly collections a wet/dry collector and a bulk collector were operated at one site and a single bulk collector at a second site. After March, 1981 the bulk collectors were abandoned and only the wet/dry collector was operated. A total of 70 samples were collected for wetfall and 63 samples for dryfall. The following constituents were analyzed on a weekly basis through March, 1981.

Soluble Fraction

- Na
- Mg
- K
- Ca
- NH_4
- NO_3
- Cl
- SO_4
- PO_4
- Fe
- Cu
- Cd
- Cr
- Hg
- Pb
- Zn

Insoluble Fraction

- Fe
- Cu
- Ce
- Pb
- Cr
- Hg
- Zn

Specific conductance and pH were also measured weekly. TOC and COD were measured weekly over a two-month period.

After March, 1981 the following constituents were measured.

NH_4
Organic N
NO_2,NO_3
P
Cl
pH
Specific Conductance
TSS
TDS
COD
As
Cd
Cu
Cr
Fe
Pb
Hg
Zn

The combined results of sampling for Lake Ellyn watershed wetfall are shown in Table 5-1. The combined results of sampling for atmospheric fallout to the watershed during dry periods are shown in Table 5-2.

The largest season for deposition of nutrients is spring. This may be due to agricultural practices outside the watershed. As expected, due to salting, winter is the most significant time for chloride deposition with total deposition greater than the three other seasons combined.

During the spring, summer and fall most ammonia and nitrate deposition comes from rainfall. Most phosphorus deposition in the spring and summer is dry fallout whereas in the winter and fall it mostly comes from precipitation. Most chloride is deposited as dryfall during the winter season. Copper fallout mostly comes through precipitation except in the winter. Atmospheric lead deposition is mostly wet fallout. Most summer, spring and fall zinc deposition is from rainfall whereas most

Table 5-1: Wetfall Quality [1]

Constituent	Summer		Fall		Winter		Spring		Total	
	Conc	Load	Conc	Load	Conc	Load	Conc	Load	Conc	Load
TSS	3.0	40.2	3.0	14.7	3.0	0.59	3.0	30.1	3.0	21.4
TDS	22.5	301	17.8	87.0	17.8	3.48	16.6	167	19.6	140
Hardness	0.60	8.03	0.86	4.2	1.18	0.23	0.63	6.32	0.66	4.70
Cl	0.21	2.81	0.23	1.12	0.36	0.07	0.25	2.51	0.26	1.85
COD	4.71	63.0	4.80	23.4	3.95	0.77	5.43	54.5	4.97	35.4
TOC	1.50	20.1	1.80	8.79	1.70	0.33	1.10	11.0	1.40	9.97
NH_4	0.36	4.82	0.28	1.37	0.49	0.10	0.47	4.71	0.42	2.99
NO_2NO_3	0.54	7.23	0.48	2.34	0.54	0.11	0.45	4.51	0.51	3.63
P	0.01	0.13	0.02	0.10	0.02	0.004	0.03	0.30	0.03	0.21
DP	0.01	0.13	0.02	0.10	0.02	0.004	0.03	0.30	0.02	0.14
Cu	0.005	0.067	0.004	0.020	0.008	0.002	0.006	0.06	0.006	0.043
DCu	0.004	0.054	0.002	0.010	0.006	0.001	0.006	0.06	0.005	0.036
Pb	0.010	0.13	0.019	0.093	0.020	0.004	0.011	0.11	0.014	0.100
DPb	0.009	0.12	0.023	0.11	0.014	0.003	0.009	0.090	0.011	0.078
Zn	0.033	0.44	0.043	0.21	0.080	0.016	0.038	0.380	0.051	0.363
DZn	0.033	0.44	0.042	0.21	0.084	0.016	0.038	0.380	0.051	0.363

(1) All concentrations in mg/l; All loads in lbs/acre/year.

Table 5-2: Dryfall Quality (lbs/acre/yr)

Constituent	Summer	Fall	Winter	Spring	Total
TSS	61.4	68.3	130	102	90.3
TDS	27.3	34.1	34.1	27.3	30.7
Hardness	5.4	5.2	4.6	6.3	5.4
Cl	0.49	1.62	3.96	0.52	1.65
COD	16.6	41.6	41.6	58.5	39.6
TOC	3.5	4.7	3.2	3.1	3.6
NH_4	0.5	0.7	0.8	1.2	0.8
NO_2	0.9	0.8	1.2	0.5	0.9
P	0.2	0.6	0.6	0.8	0.6
DP	0.05	0.01	0.07	0.09	0.06
Cu	0.013	0.009	0.026	0.016	0.016
DCu	0.006	0.003	0.010	0.006	0.006
Pb	0.036	0.078	0.055	0.062	0.058
DPb	0.004	0.004	0.004	0.004	0.004
Zn	0.068	0.101	0.198	0.088	0.114
DZn	0.052	0.068	0.149	0.039	0.077

winter fallout is from dryfall. The major reason for these differences is the distribution of dry days and precipitation days between seasons.

Vegetation

Vegetation samples were collected from trees, seeds and grass once during 1980 and once during 1981. Figure 1-3 shows the sampling sites. Samples were collected from parkway strips along high traffic, medium traffic, and low traffic streets and also from the park near Lake Ellyn away from traffic influences. A total of twelve samples were analyzed for As, Cd, Cu, Cr, Fe, Hg, Pb, Zn, BOD_5, Cl, total N, and total P. Selected results for these analyses are shown in Table 5-3.

No appreciable differences in constituent concentrations were noted among the different traffic sites and the park site. Based on the relatively high metals concentrations in vegetation it appears that atmospheric deposition may be influencing leaf and grass constituent concentrations.

Soil

The characteristics of watershed soil were investigated in two ways. First, samples from parkway soils one foot and ten feet from the curb were examined. Samples were taken from the top inch of soil in parkways along high traffic, medium traffic, and low traffic streets and also from soils in the park near Lake Ellyn, away from traffic influences (see Figure 1-3). A total of ten samples were analyzed. Samples were stratified by particle

Table 5-3: Vegetation Constituent Concentrations (ppm)

Constituent	Parkway Grass	Parkway Leaves	Parkway Seeds
Cl	12,000	4,250	2,180
BOD_5	150,000	140,000	120,000
N	23,800	21,100	---
P	3,330	1,420	---
Cu	19.8	16.0	15.0
Pb	21.5	26.9	26.0
Zn	76.7	31.3	23.0

size and analyzed for the following constituents; COD, Cl, TKN, NH_3, NO_2NO_3, P, As, Cd, Cr, Cu, Fe, Hg, Pb, Zn. Table 5-4 presents selected constituent concentrations in watershed soils.

No significant trends appear in the quality of soils one foot from the curb and ten feet from the curb except for Cu and Pb and perhaps Zn. Figure 5-1 shows the variation of soil Pb concentrations with distance from the street and compares these concentrations with road dirt concentrations by traffic volume. The influence of traffic on soil concentrations and fallout distances is readily apparent. Differences in non-metal constituent concentrations with differences in traffic volume are less pronounced. However, the difference between metals concentrations in soils influenced by traffic compared to soils not influenced by traffic is clear.

The second manner in which soils were examined was to leach simulated rainwater through columns of curbside parkway soils. Leachate results give an indication of the potential quality of pervious flow contributions. The characteristics of this simulated rainwater were pH 6.05, chloride 1 mg/l and nitrate 0.01 mg/l. In the first test all material leached from the columns was analyzed as total. In the second test only dissolved constituents were analyzed. Table 5-5 shows the results of these leachate tests.

The constituent to solids ratios (constituent concentrations x 10^6/ total solids concentration) for the leachate results shown in Table 5-5 are also similar in the < 63u range to that of area

Table 5-4: Soils Constituent Concentrations (ppm)

Constituent	High Traffic Curbside	Medium Traffic Curbside	Low Traffic Curbside	No Traffic Lake Ellyn Park
Particle Size:				
Percent < 63u	23.2	23.7	26.1	---
Percent 63-500u	50.1	50.1	52.3	---
Percent > 500u	26.7	50.0	23.8	---
Cl	26.7	50.0	23.8	---
COD	91,900	12,300	95,500	123,000
NH_3	229	253	115	87.2
NO_2NO_3	24.0	---	12.9	20.9
P	428	429	274	311
Cu	44.9	39.4	35.3	38.3
Pb	1,070	573	138	65.0
Zn	235	202	240	78.9

FIGURE 5-1: LEAD FALLOUT WITH DISTANCE FROM CURB

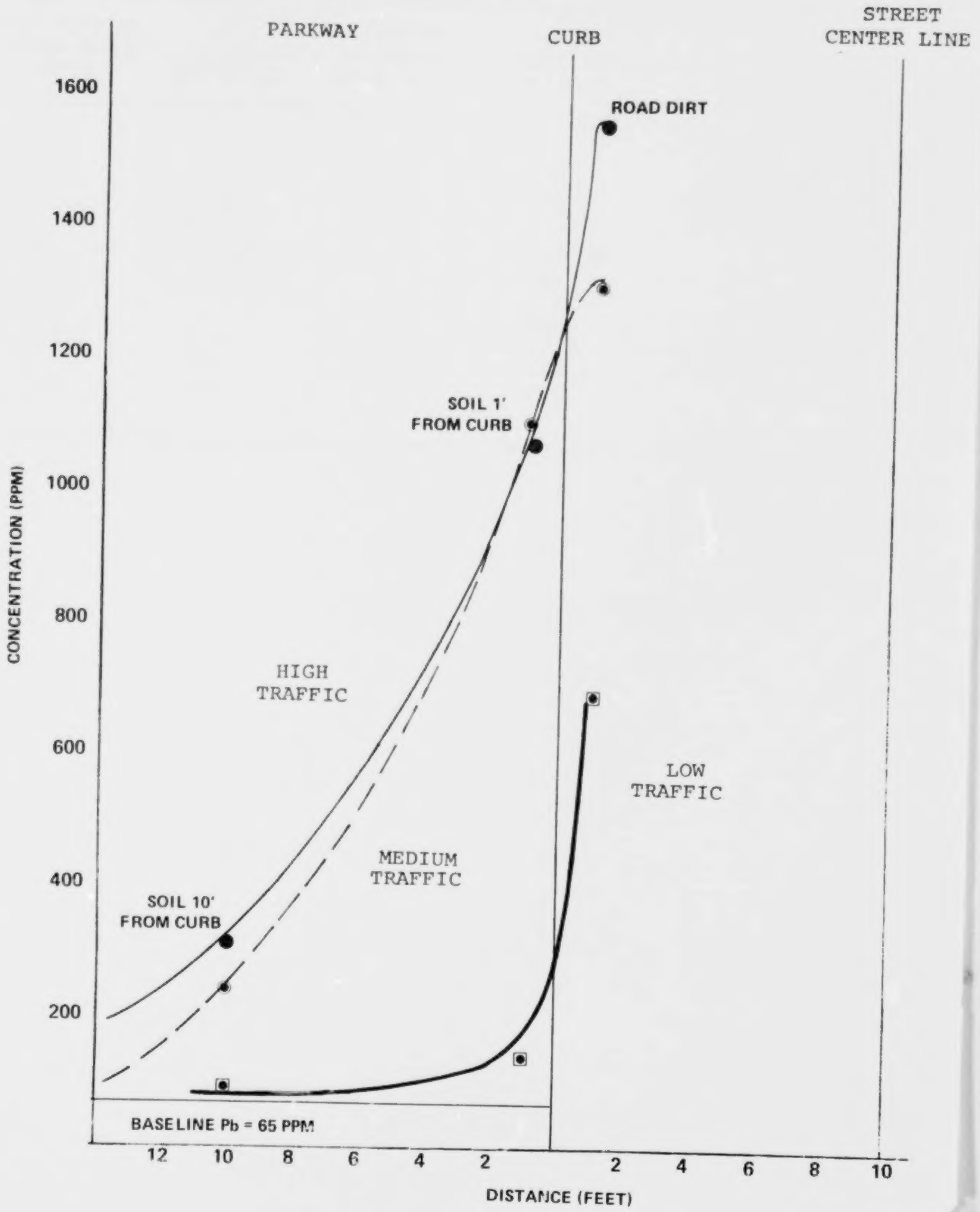


Table 5-5: Leachate Quality (mg/l)

Constituent	Total Leachate	Dissolved Constituents
TSS	3,200	---
TDS	1,000	---
Cl	7.0	9.0
COD	1,100	35
NH_3	0.6	0.5
NO_2NO_3	---	1.6
P	5.0	0.08
Cu	0.38	0.01
Pb	3.80	0.02
Zn	1.40	0.07

soils and road dirt as can be seen in Table 5-6.

Pavement Decomposition

Metals concentrations in paving materials were examined to determine the pollution potential of these sources as they decompose. Subsurface samples of asphalt pavement and concrete curbs were analyzed. The asphalt pavement was divided into aggregate and binder for analysis. Results are shown in Table 5-7 in parts per million.

Animals

The animal population of the Lake Ellyn watershed was estimated based on survey responses, actual observation and urban animal surveys conducted in other watersheds. The estimated populations and the source of the estimates are presented in Table 5-8. Wild animals constitutent loads were based on information provided by the Illinois Natural History Survey.

Survey results indicated one percent of the pet owners left their animals feces outside on paved areas. Another thirty-eight percent left it outside on grassy areas. The remainder disposed of it through other means.

Traffic

Traffic counts were made at six locations in the watershed using both automatic traffic counters and manual counts. The results of these counts verified the information in Chapter 2 which was developed by the Glen Ellyn Public Works Department. Traffic constituent loadings were not measured. Estimates were

Table 5-6: Leachate, Soils and Road Dirt -- Constituent Comparison

Constituent	< 63u Leachate (ppm)	< 63u Curbside Soils (ppm)	< 63u Road Dirt (ppm)
Cl	1,670	34	837
COD	262,000	78,800	196,000
NH_3	143	300	110
NO_2NO_3	---	9.8	168
P	1,190	523	378
Cu	90	44	378
Pb	905	664	1,420
Zn	333	229	413

Table 5-7: Pavement Constituent Concentrations (ppm)

Constituent	Asphalt Pavement	Asphalt Binder	Asphalt Aggregate	Concrete
Cu	5	0.60	4.98	8
Pb	25	0.10	26.8	34
Zn	6	1.25	5.93	15

Table 5-8: Animal Population and Unit Loads

Animal	Source	Watershed Population	Individual Total Solids Loads lbs/day	Individual Phosphorus Loads lbs/day
Dogs	(1)	600	0.060	0.002
Cats	(1)	550	0.025	0.004
Geese	(2)	100	0.066	0.002
Ducks	(2)	50	0.018	0.006
Squirrels	(3)	1,400	0.011	0.003
Rabbits	(3)	700	0.033	0.001
Other Birds	(3)	3,500	0.005	0.002

(1) Survey of Environmental Practices
(2) Actual Observation
(3) Communication with the Illinois Natural History Survey.

based on literature values and estimated gasoline consumption for the daily average of 2,660 cars traveling over the watershed's 18 miles of streets each day. Typical constitutuent concentrations in traffic related solids are shown in Table 5-9 (Shaheen, 1975).

Road Salt and Private Chemical Applications

Public and private application of chemicals to the watershed take two major forms: application of NaCl salt by the Glen Ellyn Public Works Department for deicing purposes and private applications of fertilizer and pesticides to nurture plant growth.

Salt applications to the Lake Ellyn watershed were obtained from the Glen Ellyn Public Works Department and amounted to 254 tons in 1979-80 and 139 tons in 1980-1981. Trace constituent concentrations in the salt used in Glen Ellyn were obtained by laboratory analysis of actual road salt samples (see Table 5-10).

Information concerning the private applications of fertilizers and pesticides was obtained from survey results (see Appendix A). This survey indicated that 45 percent of respondents applied fertilizers or pesticides several times a year. Based on the fact that there are 350 acres of area in the watershed which potentially could be subject to fertilizer application, this means that 158 acres receive regular fertilizer applications. Interviews with the Glen Ellyn Public Works Department indicated that they rarely apply any fertilizers to the watershed and they did not report any applications during the study period.

Survey results also indicated that about 30 percent of the

Table 5-9: Typical Traffic Related Constituent Concentrations

Source	Concentrations (ppm)[1]		
	Cu	Pb	Zn
Gasoline	4	660	10
Tires	250	1,100	620
Undercoating	1	120	110
Brake Linings	31,000	1,00	120

---

[1] Shaheen, 1975

Table 5-10: Road Salt Constituent Concentrations

Contaminant	Concentration (ppm)
Chloride	603,000
Arsenic	1.4
Mercury	0.0058
Zinc	2.0
Chronium	10.0
Iron	90.0
Cadmium	1.0
Lead	< 0.1
Copper	7.0

homeowners used pesticides at least occasionally. Based on survey responses, the most commonly used pesticides and herbicides are 2,4-D, MCPP, and Dicamba. Other pesticide and herbicide products named by respondents included sevin, diazinon and malathion.

Construction Materials

The decomposition of building construction materials results in the release of constituents to an urban watershed. Roof gutters, flashing and roof nails can be significant sources of zinc. Copper loadings can result from roof flashing and paint deterioration. Asphalt shingles can contribute metals loadings from trace contaminants. Copper, lead and zinc loadings can result from the wear of painted surfaces.

Estimates of loads resulting from paint, roofing material, gutters and other miscellaneous construction material were not measured and are difficult to estimate individually. Wearing rates can be gauged from typical design lives for these materials; 25 years for asphalt shingles, 10 years for paint and 20 years for galvanized gutters. Constituent loads from these materials were calculated from mass balance accounting and loads coming from rooftops.

Control Points

Snow

Curbside snow sampling was undertaken once in 1980 and once in 1981. Both the 1980 and 1981 sampling sites were stratified by high traffic, medium traffic, low traffic, and no traffic (see Figure 1-3). The 1980 sampling looked at constituent fallout distances by sampling snow at the curb, six feet onto the parkway and 12 feet onto the parkway. A total of 29 samples were analyzed for pH, specific conductance, TSS, TDS, Cl, COD, BOD_5, TKN, NH_3, NO_2NO_3, P, As, Cd, Cr, Cu, Fe, Hg, Pb, and Zn. Table 5-11 shows selected results of these analyses for curbside snow.

It can be noted that there is a marked correspondence between traffic volume and constituent concentrations in curbside snow. Road dirt thrown over the curbs by cars and plowing is largely responsible. The difference between snow in the park and precipitation concentrations can be explained by sublimation and dry deposition inputs over the period between snowfall and sampling. Figure 5-2 shows that most suspended constituents fall out within three feet of the curb.

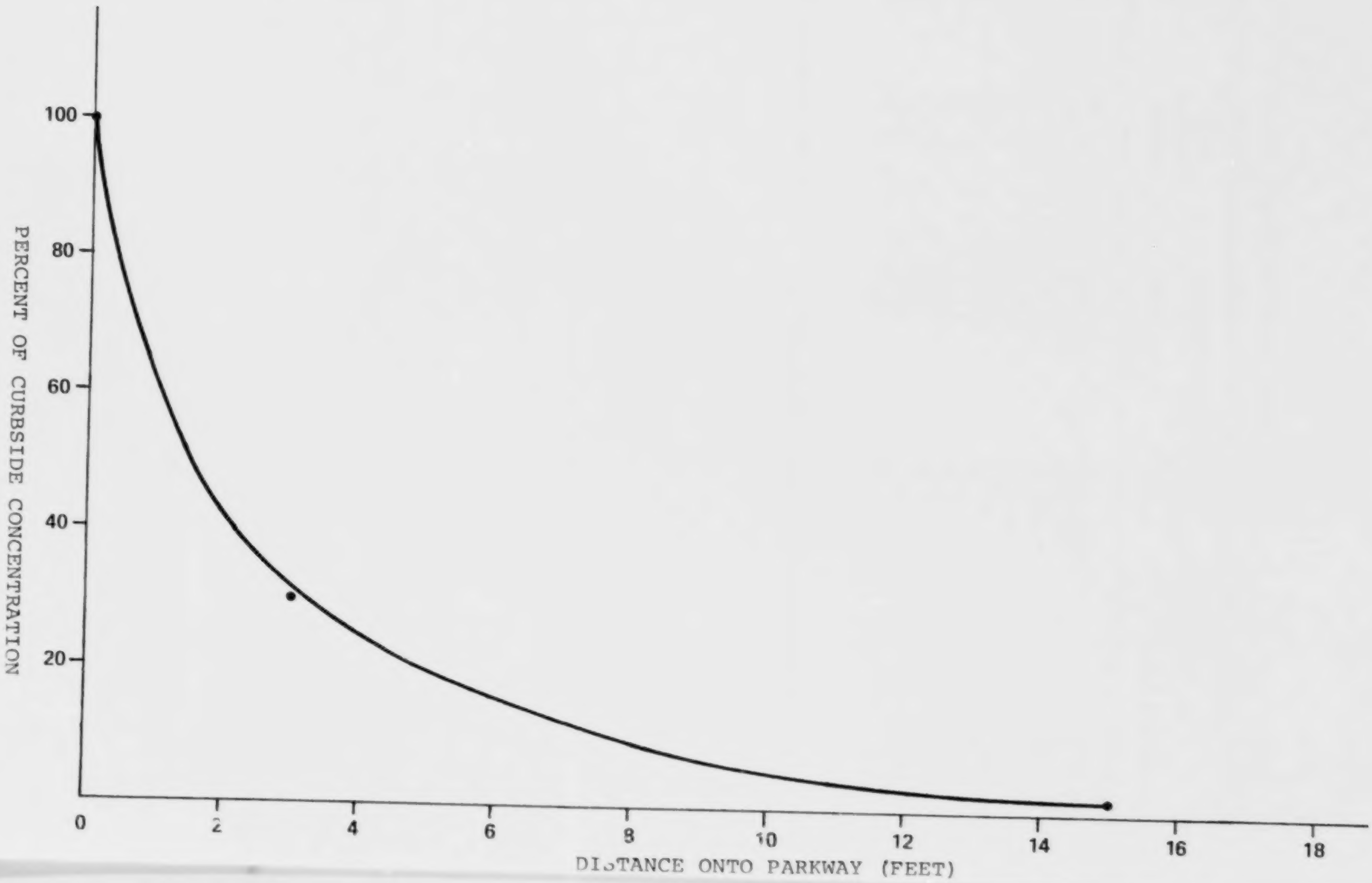
Roof Runoff

Thirty-seven roof runoff samples resulting from nineteen separate runoff events were collected. Sampling occurred at six different sites (see Figure 1-3). The sampling stations were classified by land use, roofing material, pitch, and degree of vegetal influence. The samples were analyzed for pH, specific conductance, TSS, TDS, Cl, COD, BOD_5, NH_3, TKN, NO_2NO_3, P, As,

Table 5-11: Snow Constituent Concentrations (mg/l)

Constituent	High Traffic Curbs	Medium Traffic Curbs	Low Traffic Curbs	Lake Ellyn Park
TSS	9,500	3,150	1,390	65.0
TDS	7,560	6,510	5,490	160.0
COD	3,770	1,360	931	---
Cl	4,330	3,750	1,420	9.0
NH_3	0.34	0.33	0.22	0.34
NO_2NO_3	2.02	1.77	1.06	1.20
P	4.34	2.24	01.30	0.07
Cu	0.77	0.35	0.61	0.017
Pb	12.7	5.65	3.11	0.070
Zn	5.27	1.95	0.93	0.112

FIGURE 5-2: SUSPENDED SOLIDS FALLOUT WITH DISTANCE FROM STREETS



Cd, Cr, Cu, Fe,Hg, Pb, and Zn. The classifications and number of samples collected were as follows:

Classification	Number of Samples
Commercial, flat roof, no vegetation, tarpaper and asphalt	6
Residential, peaked roof, vegetation, asphalt shingle	31

Table 5-12 presents the mean constituent quality of the runoff from these sites, as well as, stormwater and rainfall concentrations for perspective. The runoff quality from the commercial areas is generally worse than that from the residential areas, particularly with respect to total solids, COD, and Zn. Phosphorus concentrations are higher from residential roofs. A comparison of roof runoff metals concentrations with stormwater metals concentrations entering the lake reveals the relatively large metals contributions from roof runoff. Roof runoff nutrient concentrations are also as high or higher than stormwater runoff. A comparison of precipitation constituent concentrations with roof runoff reveals the amount of materials picked up by precipitation from roofs.

Catch Basins

Catch basins were sampled at the beginning and end of the study year. The samples at the beginning of the study year were composed of supernatant drawn from eight recently cleaned catch

Table 5-12: Roof Runoff Constituent Concentrations (mg/l)

Constituent	Commercial	Residential	All Roof Data	Stormwater Influent to Lake Ellyn	Rainfall
TSS	19.7	18.9	19.9	196	3.0
TDS	184	62.3	77.8	203	19.6
Cl	4.25	3.20	3.42	34.7	0.20
COD	244	91	147	95.5	4.97
P	0.20	0.58	0.41	0.48	0.03
NH_3	1.00	0.80	0.81	0.18	0.42
NO_2NO_3	0.69	0.80	0.78	0.77	0.51
Cu	0.03	0.07	0.06	0.041	0.006
Pb	0.10	0.10	0.10	0.224	0.014
Zn	1.15	0.29	0.33	0.171	0.05

basins and composited. Samples of supernatant and sludge were also drawn from eight dirty catch basins and liquid and sludge fractions were composited separately. The samples at the end of the study year were sludge only and were analyzed separately for four different sites. Sampling sites are shown on Figure 1-3. The following constituents were determined for each of the samples; Cl, COD, BOD_5, NH_3, TKN, NO_2NO_3, P, As, Cd, Cr, Cu, Fe, Hg, Pb, Zn. Percent moisture, volatile solids and particle size distribution were determined for sludge samples. TSS, TDS, pH and specific conductance were determined for supernatant samples. Table 5-13 shows the results of catch basin analyses. Catch basin sludge has a particle size distribution similar to road dirt. This results even though most of the material moved from streets is < 500u in size. Since the catch basins are more efficient in collecting larger particles they tend to reproduce road dirt particle size distributions by passing small particles and retaining larger ones. Metals concentrations are also similar for road dirt and catch basin sludge. The higher lake sediment metals concentrations reflects the smaller particle size of lake deposits.

The quality of supernatant is quite poor compared to the mean quality of stormwater influent to Lake Ellyn as can be seen in Table 5-14.

Although this supernatant is in part displaced during runoff events, the anticipated effects of this poor quality water were not apparent from the water quality measurements of stormwater reaching Lake Ellyn. There was no correlation between runoff

Table 5-13: Catch Basin Constituent Concentrations (ppm)

	Supernatant				
	Recently Cleaned Basin	Dirty Basin	Catch Basin Sludge	Road Dirt	Lake-Ellyn Sediment
TSS	38	606	---	---	---
TDS	364	290	---	---	---
Cl	100	56.8	5,610	469	---
COD	90	390	84,100	98,100	38,200
NO_3	1.9	5.8	143	70.5	988
NO_2NO_3	0.61	0.56	3.87	7.73	3,560
Total P	0.18	1.05	354	264	2,200
Cu	0.05	0.06	44.0	34.3	144
Pb	0.15	0.66	568	973	1,130
Zn	0.11	0.26	212	192	580
Percent Solids	---	---	49.3	---	30.0
Percent Volatile Solids	---	---	19.2	11.8	16.9
Percent Solids < 63u	---	---	9.4	4.2	86.7
Percent Solids 63 - 500u	---	---	26.3	32.7	13.3
Percent Solids > 500u	---	---	64.3	63.1	---

Table 5-14: Catch Basin Supernatant Versus Stormwater Runoff

Constituent	Catch Basin Supernatant	Stormwater Runoff
TSS	606	196
Cl	56.8	34.7
NH_3	5.8	0.18
NO_2, NO_3	0.56	0.77
P	1.05	0.48
Cu	0.060	0.041
Pb	0.660	0.224
Zn	0.260	0.171

volume and water quality. Smaller events did not exhibit higher constituent concentrations than larger events (see Chapter 6).

Road Dirt

Road dirt samples were collected twice during 1980 and once during 1981. Sampling was stratified by traffic volume and road surface condition. Dirt on parking lots in the watershed was also sampled during 1981. Figure 1-3 shows the location of road dirt sampling sites. A total of five to nine samples were collected in each of four different street classifications during each of the three sampling periods. In all, 20 days of sampling collected 83 samples each composed of 10 to 50 subsamples over a sampling period of 106 days. Number of samples by classification are shown below.

Classification	Number of Samples	Number of Sub-Samples per Sample
High Traffic	20	50
Medium Traffic, Fair Condition	20	45
Medium Traffic, Good Condition	16	25
Low Traffic	20	40
Parking	7	10

The road dirt samples were composited by class and particle size before analysis in each of the three sampling periods. This meant that a total of ninety-one samples were analyzed (7 particle sizes x 3 periods x 4 classes + parking). The following constituents were measured for road dirt samples.

Particle Size Distribution
(< 63u, 63-125u, 125-250u, 250-500u,)
(500-1000u, 1000-2000u,> 2000u)

COD
BOD_5
TKN
NH_3
NO_2NO_3
P
Cl

As
Cd
Cr
Cu
Fe
Hg
Pb
Zn

The results of road dirt monitoring are shown in Table 5-15. The influence of traffic on street dirt constituent concentrations is apparent. Metals concentrations are highest on high traffic streets and lowest on low traffic streets. This same general pattern of metals concentrations was noted in curbside soil and snow. High traffic streets tend to have more particles in the < 500u range. This may be due to the greater deposition of materials from traffic and to the breakup of larger particles by grinding due to greater traffic volume. The higher chloride levels on high traffic streets are the result of greater salt use during snow conditions to keep these streets passable. Nitrogen, phosphorus, and COD concentrations are highest on low traffic streets, most likely reflecting the fact that these streets, being in residential areas, have more vegetative inputs than higher traffic streets.

Total street dirt loads do not seem related to traffic volume. The high loading on low traffic streets is primarily due to lack of street sweeping. These streets are swept only one-fifth as often as high traffic streets.

Table 5-15: Road Dirt Constituent Concentrations (ppm)

Constituent	High Traffic				Medium Traffic				Low Traffic			
	<63u	63-500u	>500u	Total	<63u	63-500u	>500u	Total	<63u	63-500u	>500u	Total
Total Mass (lbs/curb-mile)	52.7	336	435	824	25.6	179	332	525	28.8	251	600	879
Percent Mass	6.3	41.0	52.7	100	5.0	34.4	60.6	100	3.4	30.4	66.2	100
Cl	1,510	1,540	683	1,090	1,080	731	434	568	445	335	309	322
COD	151,000	93,200	70,500	84,900	178,000	108,000	59,400	82,000	223,000	127,000	99,500	112,000
NH_3	66.7	60.4	56.2	58.6	130	94.5	84.0	89.9	106	83.0	42.3	56.8
NO_2NO_3	27.0	6.3	3.0	5.90	14.5	4.75	7.1	6.67	16.0	14.6	5.7	8.76
P	325	249	149	201	323	260	242	252	440	280	274	281
Cu	131	102	28.9	65.3	82.8	68.3	23.0	41.6	52.3	36.8	18.3	25.1
Pb	2,130	2,630	649	1,550	1,850	2,200	764	1,312	850	1,080	434	645
Zn	605	576	266	414	442	410	88.7	217	335	243	94.8	148
Percent Volatile Solids	10.2	7.2	7.9	7.8	10.0	8.4	10.0	9.4	12.9	8.5	16.8	14.1

A comparison of road dirt constituent concentrations with concentrations in curbside soils is presented in Table 5-16. It is readily apparent from this table that erosion of curbside soils is capable of providing an explanation for the COD, NH_3, NO_2-NO_3 and phosphorus found in road dirt. Metals concentrations are also high enough to explain a significant fraction of the concentrations found on the streets. Chloride does not seem to accumulate in curbside soils and is probably readily washed off or leached to shallow groundwater.

It was observed that rainfall impacted both the quantity of road dirt loads and the particle size distribution of those loads. Observations of road dirt loads measured before and after rainfall yielded the following data. The load of solids < 63u in diameter decreased in 60 percent of the observations. The percentage of material in street dirt < 63u decreased in 75 percent of the cases. Load 63-500u in size decreased in 60 percent of the observations. The relative amount of material 63-500u decreased 67 percent of the time. Loads > 500u increased in 60 percent of the cases. The percentage of street dirt > 500u increased 75 percent of the time. Due to difficulties in obtaining samples immediately before and after rainfall, effects other than rainfall may be represented in these observations but the overall trends are still clear. Runoff is most effective in moving particles < 500u and relatively ineffective in moving particles above that size in this watershed. The particle size distribution of materials reaching catch basins entering the lake

Table 5-16: Road Dirt Versus Curbside Soil (ppm)

Constituent	High Traffic		Medium Traffic		Low Traffic	
	Dirt	Soil	Dirt	Soil	Dirt	Soil
Cl	1090	26.7	568	50.0	322	23.8
COD	84900	91900	82000	12300	112000	95500
NH_3	58.6	229	89.9	253	56.8	115
NO_2NO_3	5.90	24.0	6.67	12.9	8.76	20.9
P	201	428	252	429	281	474
Cu	65.3	44.9	41.6	39.4	25.1	35.3
Pb	1550	1070	1312	573	645	138
Zn	414	235	217	202	148	240

in stormwater runoff and settling in the lake also supports this conclusion with over 95 percent of the material at these points < 500u.

The fact that street loads < 500u increase 40 percent of the time and loads > 500u increase 60 percent of the time indicates the contribution of pervious runoff to street dirt solids.

During periods without rainfall or street sweeping, loads < 63u were observed to increase 65 percent of the time. The percentage of road dirt < 63u increased in 55 percent of the cases. Loads 63-500u increased 75 percent of the time but their relative percentage of total street dirt decreased 60 percent of the time. The load of particles > 500u increased 75 percent of the time. The relative amount of material > 500u in street dirt decreased in 55 percent of the observations.

Increases in road dirt loads in the absence of rain or sweeping activity are the result of traffic, dryfall, vegetation and windblown dust. The more rapid rate of accumulation of the < 63u fraction represents the smaller particle size of loads from the principal sources during these periods and also reflects the grinding of larger particles into smaller particles by traffic action.

Of final note was the observation of no difference in loadings between fair condition streets and good condition streets. The lack of statistical difference for solids loadings of various sizes for good condition versus fair condition streets is probably due to the fact that there is little stratification in the quality of Glen Ellyn's streets. Fair condition streets did produce slightly higher loads than good condition streets except for the < 63u particle sizes where good condition streets had higher loads than fair condition streets. This suggests there may be marginally higher decomposition of street surfaces on fair condition streets as compared to good condition streets, resulting in more particles of larger size due to pavement wear.

Street Sweeping

Materials collected in the hopper of Glen Ellyn's street sweeper were sampled during each of the road dirt sampling programs. Samples were analyzed by particle size for total volatile solids, Cl, COD, BOD_5,NH_3, TKN, NO_2NO_3, P, As, Cd, Cu, Cr, Fe, Hg, Pb, and Zn. The results of these analyses are shown in Table 5-17.

Records kept by Glen Ellyn Public Works Department personnel indicated that 26 hopper loads of material were removed from the Lake Ellyn watershed during 35 sweeping trips in the study year.

A comparison of these data with those obtained for street dirt reveals that street sweepings contain more solids > 500u and more volatile solids. Within particle size groups, constituent concentrations are similar. However, the overall impact of sweeping on pollutant loads and concentrations is lessened because of its pronounced tendency to pick up proportionally fewer particles < 63u than are found in road dirt. This is of particular significance since the constituent loads moved by stormwater are largely < 63u.

Table 5-17: Street Sweepings Constituent Concentrations (ppm)

Constituent	< 63u[1]	63-500u[1]	> 500u[1]	Total[2]
Mass (Percent)	2.5	21.8	75.7	100.0
COD	186,000	118,000	68,000	105,000
Cl	1,072	307	321	276
NH_3	285	123	117	71.3
NO_2NO_3	9.81	6.60	4.80	3.56
Total P	414	278	120	136
Cu	77.3	57.8	21.7	34.4
Pb	1,140	926	287	543
Zn	472	329	115	196
Percent Volatile Solids	11.0	6.0	17.8	15.0

[1] Based on two observations

[2] Based on three observations, including the first two.

Examination of street dirt loads before and after sweeping yielded the following data. Loads of street dirt < 63u decreased in 60 percent of the observations. The percentage of material < 63u increased, however, in 90 percent of the cases. Loads 63-500u in size decrease 75 percent of the time but the percentage of these materials relative to total load increased 85 percent of the time. Loads > 500u decreased for all observations and the relative percentage of these materials decreased 85 percent of the time.

The greater efficiency of sweeping on particles > 500u is readily apparent. While reducing loads in all size categories sweeping increased the relative amount of material < 500u. The greater efficiency of sweeping on larger particles can also be seen from the particle size distribution of material from the sweeper hopper as previously noted.

Lake Sediment

Both the quantity and quality of Lake Ellyn sediment was investigated. A series of nine sample sets from three different locations were collected over a period of two years. Sample sites are shown in Figure 1-3. These samples were analyzed by particle size for percent moisture, volatile solids, pH, COD, NH_3, TKN, NO_2,NO_3, P, As, Cd, Cr, Cu, Hg, Pb, Zn, and SOD @ 20^oC. The results of these measurements were discussed in Chapter 3.

Groundwater

Groundwater data were collected from four sites during the winter, spring, and summer of 1981 (Figure 1-3). A total of 22 samples were analyzed for specific conductance, pH and total residue upon evaporation. Another four samples were analyzed for alkalinity, Ba, Be, Cd, Ca, Cl, Co, Cu, DOC, Hardness, Fe, Pb, Li, Mg, Mn, Mb, K, Si, SO_4, Na, Sr, Vn, and Zn. Samples were drawn from two wells finished at depths of 33 feet and 30 feet at the south and north ends of the lake, respectively. Samples were also collected from clusters of lysimeters at depths of 10 feet, 13 feet, and 16 feet on the north and south ends of the lake. The results of this monitoring are presented in Table 5-18 along with the quality of influent baseflow to the lake.

From the results in Table 5-18 it appears that the storm sewers of the watershed act to drain shallow groundwater to the lake since the similarities between groundwater and baseflow constituent concentrations are readily apparent.

A recent report from the Illinois State Water Survey notes that the quality of the shallow dolomite aquifer near Glen Ellyn is also very similar to the quality results obtained above. Typical constituent concentrations are chloride 150 mg/l, TDS 800 mg/l, and Na 171 mg/l (Sasman, 1981).

This again points out the migration of road salt to shallow groundwater. Since the source of public water supply to the Lake Ellyn watershed is shallow dolomite groundwater as noted previously, water supply system leaks may be another source of constituents found in baseflow to the lake.

Table 5-18: Lake Ellyn Groundwater Monitoring Results

	Inlet Baseflow	South Well	South Lysimeters			North Well	North Lysimeters		
			1	2	3		4	5	6
Depth	4-10'	33'	10'	13'	16'	30'	10'	13'	16'
Cl	156	120	130	140	140	430	300	160	120
Cu	6	11	8	6	3	4	4	4	5
Pb	5	3	5	1	1	1	5	1	1
Zn	24	20	30	20	10	50	15	15	10
TDS	903	704	1,200	2,100	1,470	2,000	2,110	1,560	1,160
Na	---	69	157	165	130	138	95	67	61

Water Column

Water column quality in Lake Ellyn was examined by means of four three-day surveys. These surveys were conducted in July, August and October of 1980 and in April of 1981. Observations of dissolved oxygen, temperature, pH, alkalinity, and chlorophyll a were taken every other hour at varying depths for one day of each three. Depth integrated observations for the constituents listed below were taken on the other two days at noon and midnight. Hg and As were analyzed in only the July samples. The results of these surveys were presented in Chapter 3.

- Chloride
- COD
- PO_4
- Diss. PO_4
- Ortho PO_4
- Diss. Ortho PO_4
- NH_3
- Diss. NH_3
- Diss. NO_2 NO_3
- TDS
- TSS
- Fe
- Cd
- Cu
- Pb
- Hg
- Zn
- Cr
- As
- Diss. Fe
- Diss. Cd
- Diss. Cu
- Diss. Pb
- Diss. Hg
- Diss. Zn
- Diss. Cr
- Diss. As
- Kjeldahl-N
- Diss. Kjeldahl-N
- Organic-N
- Diss. organic-N

CHAPTER 6: MATERIALS BUDGETS AND ASSESSMENT OF SOURCE CONTROL

Control Point Budgets

Constituent mass balances for total solids, Cl, P, Cu, Pb, and Zn were developed based on loads calculated from the data presented in the previous chapter. Table 6-1 presents constituent concentrations for this data in parts per million parts of dry solids. This table is important because it gives an immediate indication of the potential sources of constituents to control points as well as a check on the flux of these materials through these points. For example, it is apparent that traffic, soils near curbs, roof runoff, precipitation and dryfall are the only sources which have a high enough ratio of metals to solids to cause road dirt to have the metals to solids ratio it exhibits. Pavement, vegetation, and soils not influenced by traffic do not contain enough of these metals to achieve the final ratios observed in solids on the street. At the same time, it can be noted that the ratios of constituents in the < 500u fraction of road dirt, inflow to the lake, and bottom sediments are also generally similar as they should be since presumably the smaller street solids are being mobilized by rainfall, washed to the lake and are settling to the lake sediments. Constituent mass balances around the five control points follow.

The relative accuracy and usefulness of these material budgets is, of course, dependent on the amount of error in the supporting data. Although all of the measurements in the preceding section were obtained using recognized analytical and quality control

Table 6-1: Constituent Concentrations Relative to Total Solids (ppm)

	Cl	P	Cu	Pb	Zn	NH_3	NO_2NO_3	COD
Road Dirt								
< 63u	790	385	59	1,350	403	110	16.7	199,00
63-500u	570	271	44	1,580	326	85	10.7	118,000
> 500u	435	272	23	604	130	60	6.2	93,600
Total	491	276	31	934	201	70	8.0	105,000
Road Salt	600,000	---	7	< 0.1	2	---	---	---
Catch Basin	5,620	356	46.4	567	211	143	3.87	84,100
Curbside Snow	314,000	220	33	559	192	45	231	211,000
Rooftop Runoff	35,000	4,200	614	1,023	3,380	8,290	7,980	1,500,000
Traffic								
Rubber	---	---	250	1,100	620	---	---	---
Brake Linings	---	---	31,000	1,100	120	---	---	---
Inflow to Lake	110,000	1,080	103	583	438	438	1,800	23,400
Vegetation								
Grass	12,000	3,330	19.8	21.5	76.7	---	---	---
Leaves	4,250	1,420	16.0	26.0	31.3	---	---	---
Pavement								
Asphalt	---	---	5.0	25.0	6.0	---	---	---
Concrete	---	---	8.0	34.0	15.0	---	---	---
Street Sweepings	276	136	34.4	543	196	71	3.6	105,000
Lake Sediment	---	2,200	144	1,130	580	988	3,560	38,200
Soils								
Parkway	34	444	39	484	218	300	9.8	78,800
Lake Ellyn Park	---	311	29.2	65	78.9	87.0	20.9	123,000
Precipitation	11,500	1,327	265	619	2,260	18,600	22,600	220,000
Dryfall	13,300	4,670	166	500	917	6,600	7,400	327,000

procedures, some error in measurement accuracy is still present. Another important source of error is the large amount of inherent variability in these data. Every effort was made to gather sufficient numbers of samples to characterize this variability and hence obtain a better understanding of the true importance of various sources and sinks. However, the list of constituents and their potential sources and sinks is long and costs were finite so some compromises were necessary.

Further, the use of the term "source" needs qualification. Although we characterize materials such as atmospheric deposition or vegetation as a source, they are not primary sources in the sense that they cannot be reduced to some other contributor. The constituents in atmospheric deposition, for example, may result from traffic and power plant emissions many miles from the Lake Ellyn watershed. Constituent concentrations in vegetation may be influenced by atmospheric deposition and traffic. Identifying such primary sources was beyond the scope of this project. The compromise which was reached involved the use of the word source for the principal constituent contributors within the watershed while recognizing the interactions between these sources.

Lake Ellyn

Table 6-2 presents the materials budget for Lake Ellyn. The lake receives inputs from roof runoff, stormwater runoff, baseflow, vegetation, animals, and atmospheric deposition. Constituents leave the lake in stormwater during wet periods and baseflow during dry periods. Accumulated material settles to

Table 6-2: Lake Ellyn Materials Budget (Loads in Pounds)

	Total Solids	Solids < 63u	Solids 63-500u	Solids > 500u	Cl	P	Cu	Pb	Zn
LOADS IN									
Roof Runoff	9,250	8,920	330	---	208	14.2	1.9	5.1	50.5
Stormwater	363,000	331,000	32,000	---	40,600	388	36.3	212	112
Baseflow	558,000	557,000	1,000	---	95,400	300	3.7	3.0	15.0
Vegetation	21,000	20,000	1,000	---	85	28.5	0.3	0.5	0.7
Animals	411	411	---	---	---	14.2	---	---	---
Precipitation	1,610	1,610	---	---	16	1.3	0.4	0.9	2.6
Dryfall	1,200	1,200	---	---	16	5.6	0.2	0.6	1.1
Total	954,000	920,000	34,000	---	136,000	752	42.8	222	182
LOADS OUT									
Stormwater	449,000	448,000	1,000	---	115,000	197	5.99	22.8	26.8
Baseflow	254,000	254,000	---	---	66,000	83.8	2.09	6.40	9.95
Total	703,000	702,000	1,000	---	181,000	281	8.10	29.2	36.8
ACCUMULATION	251,000	218,000	33,000	---	-45,000	471	34.7	193	145

Lake Ellyn's bottom as sediment. There is no direct interaction between groundwater and the lake.

Eighteen percent or 14.5 acres of watershed roofs are hydraulically linked to watershed storm sewers. It was estimated that 50 percent of these roofs flowed directly into storm sewers and the remaining 50 percent flowed to streets which then flowed directly to catch basins and storm sewers. Based on 31.5 inches of effective (runoff producing) rainfall during the study year, and the measured roof runoff concentrations weighted by percentage of roof in each classification, the total roof runoff loads to storm sewers were calculated.

The stormwater loads to the lake are based on the flow statistics in Chapter 4 and the concentration data in Chapter 7. Stormwater influent loads were reduced by the amount of roof runoff loads previously calculated. The particle size distribution of the solids load to the lake was measured as shown below.

Station	Percent < 63u	Percent 63-500u	Percent > 500u
Inlet	82.5	17.5	-
Outlets	97.9	2.1	-

Some material > 500u undoubtedly enters the lake. These larger solids were not included in the loads measurements due to the difficulty in sampling them. However, this load is insignificant in relation to stormwater loads based on particle size work completed in the area where these particles would settle in the lake.

Baseflow loads and assumptions are also based on flow statistics reported in Chapter 4 and concentration data reported in Chapter 7. The particle size distribution of baseflow loads was assumed to be the same as stormflow loads at the outlets and greater than 99 percent < 63u at the inlet.

Vegetation loads to the lake are almost entirely leaf fall. Loading from grass clippings in the park surrounding the lake are insignificant. A full canopy of mature trees, mostly maples, reach to within 15 feet of the water on two sides of the lake. Based on the proximity of these trees it was assumed that 50 percent of the lake would be subject to falling leaves. Unit leaf fall loadings were assumed to be 4,000 lbs/acre/year dry solids based on literature values. (U.S. Environmental Protection Agency, 1977). Given the 10 acres surface area of the lake, loads were developed by multiplying the measured vegetal constituent concentrations by the leaf fall unit loading times 50 percent of the lake area.

The principal sources of animal load contributions to the lake are geese and ducks. It was assumed that geese are present in the watershed for 3 months of the year and ducks for 8 months of the year. Loads were developed from these assumptions and the unit loads presented in Chapter 5.

Atmospheric deposition loads to the lake in the form of precipitation and dryfall were based on the surface area of the lake and the measured unit loads.

The specific gravity of solids in Lake Ellyn was determined to be 1.73. The solids content of lake sediment was measured as

32.6 percent. Using these values and the sediment volume of 207,000 cubic feet the total sediment load was calculated to be 6,720,000 pounds. Based on the measured sediment constituent concentrations, there would be 14,800 pounds of phosphorus, 968 pounds of Cu, 7,590 pounds of Pb, and 3,900 pounds of Zn in lake sediment. Lake Ellyn was last dredged in 1970. At that time about 35,000,000 pounds of material were removed to deepen the lake. This load is based on design specifications and not on as built conditions which are not known. Based on the difference between inlet and outlet total solids loads for the lake, about 250,000 pounds of material are deposited by stormwater to the lake each year. Over 10 years this would yield about 2,500,000 pounds of sediment. The difference between this number and the 6,720,000 pounds measured for the lake is due to sediments not actually removed during the 1970 project.

Based on the water column data presented in Chapter 3, there was no significant accumulation of constituents in the Lake Ellyn water column during the study year.

Clearly the most important sources of solids and constituents to Lake Ellyn are stormwater and baseflow. Stormwater is the most important source of P, Cu, Pb and Zn. Baseflow contributes the most solids (albeit in a dissolved state) and chloride. 49 percent of the stormwater solids entering the lake are suspended (see Table 7-24). Virtually all of these materials settle to the lake bottom. The other 51 percent of stormwater solids and 99 percent of baseflow solids are dissolved. Very little of this material is precipitated to the lake bottom.

An examination of constituent to solids ratios for influent to the lake and "budgeted" lake sediment reveal that they are similar to constituent concentrations in Lake Ellyn sediment. Based on the stormwater total suspended solids load to the lake of 184,000 pounds (see Chapter 7) constituent to suspended solids ratios were calculated. These should be very similar to lake sediment constituent concentrations. This was indeed the case as can be seen in Table 6-3. When the constituent to solids ratios in the "budgeted" lake sediment are compared to observed sediment concentrations there is again very close agreement.

Another comparison can be made based on the particle size distribution of solids in the stormwater suspended solids to the lake, the "budgeted" bottom sediment, and the actual bottom sediment. Again these percentages are quite consistent as shown below.

Particle Size	Stormwater TSS	"Budgeted" Lake Sediment	Actual Lake Sediment
< 63u	82.5	86.9	86.7
63 - 500u	17.5	13.1	13.3
> 500u	-	-	-

Seventy percent of the chloride entering the lakes comes from baseflow. It appears that almost all of this material comes from road salt either via subsurface runoff on leakage from the local water supply system.

Lake Ellyn's high retention of phosphorus and metals results from the fact that most of these constituents are attached to particulate matter which settles to the lake bottom.

Table 6-3: Comparison of Stormwater Solids and Lake Sediment (ppm)

Constituent	Stormwater Constituent/TSS Ratio	Actual Lake Sediment	"Budget" Lake Sediment
P	2,180	2,200	1,880
Cu	208	144	138
Pb	1,180	1,130	769
Zn	886	580	577

Catch Basins

Catch basins receive inputs from street washoff. Baseflow and roof runoff contributions to catch basins are insignificant. Constituents leave catch basins in stormflow. Accumulated materials settle to the bottom of the catch basin. The constituent materials budget around watershed catch basins is presented in Table 6-4.

Stormwater loads from catch basins are the same as stormwater influent loads to Lake Ellyn adjusted for roof runoff. Street washoff loads were calculated from catch basin accumulation plus loads leaving catch basins.

Catch basin sludge accumulations were based on the 364 catch basins in the watershed, the average catch basin diameter of 32 inches, the mean sludge accumulation of 2.92 inches over one year, 49.2 percent solids in catch basin sludge, and a solids specific gravity of 1.70. Constituent loads were determined from the measured values presented in Chapter 5.

Based on the supernatant characteristics of clean catch basins versus those in which material had accumulated for a year, it was decided that constituents accumulated in catch basin supernatant. The mass of these constituents was calculated using the mean catch basin supernatant depth of 24.3 inches, the mean catch basin diameter of 32 inches, and the constituent concentration difference between clean and dirty catch basin supernatant.

Catch basins in the Lake Ellyn watershed capture about six percent of total influent solids. They capture about 10 percent

Table 6-4: Catch Basin Materials Budget (Loads in Pounds)

	Total Solids	Solids < 63u	Solids 63-500u	Solids > 500u	Cl	P	Cu	Pb	Zn
LOADS IN									
Street Washoff	385,000	335,000	37,000	12,500	40,700	406	37.3	225	118
Total	385,000	335,000	37,000	12,500	40,700	406	37.3	225	118
LOADS OUT									
Stormwater	363,000	331,000	32,000	---	40,600	388	36.3	212	112
Total	363,000	331,000	32,000	---	40,600	388	36.3	212	112
ACCUMULATION	22,200	4,620	5,100	12,500	124	8.0	1.0	12.7	4.7

of influent suspended solids. However, catch basins remove only about two to five percent of the phosphorus and metals in street washoff. Based on the measured accumulations of materials in catch basins during the study year, about 10 percent of the capacity of a typical basin is filled during the year.

It is apparent that catch basins have little effect on the quality of stormwater entering Lake Ellyn. A comparison of data in Table 6-1 for road dirt, catch basin sludge and stormwater influent to Lake Ellyn points out the fact that catch basin sludge contains fewer constituents than stormwater but about the same amount as road dirt (see Table 6-5).

As previously mentioned, the similarity between road dirt and catch basin constituent concentrations is due to the differential efficiency of catch basins in settling out particles of different sizes. Although about 95 percent of the material leaving the streets is < 500u in size, only 35 percent of the material in catch basins is < 500u. The difference between stormwater constituent to solids ratios and catch basin sludge points out how inefficient the basins are in removing smaller particles.

Streets and Parking Lots

The materials budget around watershed streets and parking lots is presented in Table 6-6. Streets and parking lots receive inputs from atmospheric deposition, pervious runoff, traffic, decomposition of paved surfaces, animals, vegetation, roof runofftraffic, decomposition of paved surfaces, animals, vegetation, roof runoff, and road salt. Materials are removed

Table 6-5: Catch Basin Sludge Versus Road Dirt and Stormwater Solids

Constituent	Stormwater	Road Dirt	Catch Basins
P	2180	276	354
Cu	208	31	44
Pb	1180	934	568
Zn	886	201	212

Table 6-6: Streets and Parking Lots Materials Balance (Loads in Pounds)

	Total Solids	Solids < 63u	Solids 63-500u	Solids > 500u	Cl	P	Cu	Pb	Zn
LOADS IN									
Precipitation	10,700	10,700	---	---	106	8.9	2.5	5.7	17.4
Dryfall	8,230	8,230	---	---	106	37.2	0.9	3.8	7.5
Pervious Runoff	510,000	190,000	127,000	193,000	743	270	20.4	247	111
Traffic	30,000	30,000	---	---	---	---	34.8	330	56.7
Paved Surface Decomposition	361,000	59,000	48,000	254,000	---	---	1.8	9.0	2.2
Animals	2,840	2,840	---	---	27	91.7	---	---	---
Vegetation	30,000	28,000	2,000	---	210	61.0	0.5	0.7	1.5
Roof Runoff	9,250	8,920	330	---	208	14.2	1.9	5.1	50.5
Road Salt	278,000	278,000	---	---	168,000	---	1.9	---	0.6
Total	1,240,000	616,000	174,000	447,000	170,000	483	64.7	601	247
LOADS OUT									
Street Sweepings	576,000	14,400	135,000	427,000	158	78.3	19.7	312	113
Washoff	385,000	335,000	37,000	12,500	40,700	406	37.3	225	118
Displaced Road Dirt	269,000	266,000	3,600	---	129,000	---	7.2	56.9	13.7
Total	1,230,000	616,000	174,000	440,000	170,000	480	64.4	594	245
ACCUMULATION	10,200	350	3,100	6,750	3.2	2.9	0.3	6.6	1.5

from these areas by street sweeping, stormwater washoff and displacement of street dirt by traffic. In addition to these inputs and outputs, there is the possibility of accumulation of materials on streets and parking lots. The materials budget is constructed around only those streets and parking lots which are directly connected to watershed storm sewers. All other paved areas are included in the balance around pervious areas.

Atmospheric deposition loads to streets and parking lots were determined from the measured unit loading rates in Chapter 5 multiplied by the 68.6 acres of streets and parking areas in the watershed.

Animals which potentially can contribute waste to streets include dogs, cats, birds, squirrels, and rabbits. Based on survey responses, it was assumed that one percent of the potential dog and cat load was deposited on streets and parking areas. Bird, squirrel, and rabbit loads were estimated to be 13 percent of the loads are presented in Chapter 5. This figure represents the percentage of total land cover which streets and parking areas occupy.

Unit vegetal loadings are based on an annual total mass loading of 4000 lbs/acre/yr for leaves and 3700 lbs/acre/yr for grass as discussed previously. Survey results indicated that about 33 percent of the residential areas of the watershed are covered by tree canopy. Five percent of the commercial areas are covered by trees. This translates to 11.3 acres of streets and parking lots being affected by leaf fall. Based on this figure and the measured constituent concentrations, the following annual leaf loads in pounds were developed.

Total Solids	Cl	P	Cu	Pb	Zn
45,200	192	64.4	0.7	1.1	1.5

Grass loads in the table below are based on a grassed area of 350 acres in the watershed. Since only a narrow strip of parkway grass clippings can be blown onto the street during mowing and since, even at that, the mower must have a side discharge pointed to the street, it was estimated that only 10 percent or 5.2 acres of grassed parkway area contribute grass clippings to streets. Since survey results indicated that 2.8 percent of homeowners raked clippings to the street this would add another 1.5 acres of contributing area for a total of 6.7 acres. Based on this area and the measured constituent concentrations for grass, the following loads were developed

Total Solids	Cl	P	Cu	Pb	Zn
24,800	297	82.4	0.5	0.5	1.9

Roof runoff loads to streets were estimated to be the same as roof runoff loads to storm sewers. Total roof runoff loads to catch basins and streets were calculated from the 14.5 acres of roofs tributary to these points, the 31.5 inches of effective rainfall during the study year, and measured constituent concentrations.

As discussed previously, Glen Ellyn applied about 139 tons of road salt to the watershed during the study year. Trace constituent loads were calculated from the concentrations presented in Chapter 5.

It was estimated that 33 percent of the solids and lead loads from traffic were deposited directly to the street. The remaining 67 percent was deposited on pervious areas, particularly parkways. This loading seems reasonable in view of Figure 5-1. If the curve of that figure is assumed to represent the curve of traffic fallout , then about one-third of the area under that curve is between the curb and the street centerline. Based on the traffic Pb concentrations in Chapter 5 and consumption of 15 miles per gallon in a fleet of which 33 percent of the vehicles burn regular gas and 50 percent of the lead in gasoline is delivered as fallout, a total of about 1,000 pounds of lead would be deposited annually to the watershed. Total solids deposition would be 90,000 pounds based on Shaheen's number of 2.38×10^{-3} lbs/axle-mile/day. The loads of other constituents were obtained by difference in the mass balance calculation.

Solids loads from pervious runoff were obtained by difference in the mass balance calculations. It was assumed that solids in pervious runoff would have the measured curbside soil constituent concentrations.

Total solids loads from paved surface decomposition were obtained by difference from the mass balance computations. It was assumed that solids from this source would exhibit the measured constituent concentrations. The total calculated load coming from paved surface decomposition amounts to about 0.01 inch per year over these areas.

Based on the hopper volume of 7.4 cubic yards in Glen Ellyn's street sweeper, 26 hopper loads of material per year, and a specific gravity of 1.76 for sweeper solids, the total solids load removed by street sweeping during the study year was calculated to be 576,000 pounds. Constituent loads were determined by applying the measured concentrations in Chapter 5 to this load.

Street washoff was assumed to include all material washed from or over streets including pervious runoff and roof runoff and is the same as the street washoff in the materials budget around catch basins.

Estimates of road dirt displaced from streets to pervious areas were based on the accumulation of constituents in watershed snowpack. Theoretically, the only sources which would be contributing constituents to area snowpack would be traffic, atmospheric deposition, salt applications and road dirt sprayed onto the parkway by traffic. The constituent to solids ratios shown in Table 6-1 for the snowpack, pavement, dustfall, park soil and the < 63u fraction of road dirt and curbside soil reveals the similarity between snowpack, road dirt and curbside soil constituent concentrations. This suggests that the constituents measured in snowpack mostly result from road dirt being splashed into the snow from streets and curbs by traffic. This indicates that traffic can be an important agent in causing material to be transferred from streets to pervious areas. The magnitude of this flux can be estimated from the mass of constituents in the snow pack, divided by time of accumulation and traffic and adjusted for precipitation and dryfall contributions.

Total loads to pervious areas from streets due to traffic action are presented below. Loadings are based on 36 miles of pervious parkway and a maximum fallout distance of twelve feet for a total area of 52 acres. In addition, salt load not measured in washoff from streets and parking areas was added to these numbers resulting in an additional 201,000 pounds of solids and 121,000 pounds of chloride.

Total Solids	Cl	P	Cu	Pb	Zn
269,000	129,000	-	7.2	56.9	13.7

These loads assume that the process of street dirt displacement continues at a similar rate in other seasons as it does in winter. Of interest is the absence of phosphorus in this transfer process. This suggests that phosphorus sources are not as active in winer as in other seasons (i.e., vegetation and fertilizer applications).

The total accumulation of road dirt was calculated based on an examination of road dirt loads over the project year which showed increases in total road dirt loads in all traffic classifications. These increases were as follows:

High Traffic	135 lbs/curb-mile
Medium Traffic	75 lbs/curb-mile
Low Traffic	1000 lbs/curb-mile

This accumulation is unique to this study year and should not be interpreted as a long-term trend since road dirt loads in the long term are in equilibrium. Weighting these loads by curb miles of streets in each traffic classification yielded a total increase of 569 lbs/curb mile or 10,200 pounds over the watershed. No increase was assigned to loads in parking areas since insufficient data to formulate an estimate was available. Also, loads in parking areas tend to be influenced only by runoff and wind effects and not by sweeping, hence total loads may be more stable. Concentrations shown in Table 5-15 for low traffic were used to estimate constituent loads in accumulated road dirt. Low traffic concentrations were used because about 95 percent of the accumulation occurred on these surfaces due to a change in sweeping frequency.

The major sources of solids to streets and parking areas are pervious runoff, paved surface decomposition, and road salting. Most of the road salting material is soluble and is displaced by traffic to parkway soils. Over 50 percent of the phosphorus load comes from pervious runoff. Other significant phosphorus sources appear to be animals and vegetation. Fifty-four percent of the copper load is deposited directly on streets and parking areas by traffic. Another 32 percent comes from pervious runoff. About 55 percent of the lead load is deposited directly on streets and parking areas by traffic. Another 41 percent comes from pervious runoff. The major sources of zinc inputs to streets and parking areas are pervious runoff (45 percent), traffic (23 percent), and roof runoff (20 percent). Virtually the entire chloride load comes from road salting. Other contributions are all less than 0.5 percent and are probably influenced to some extent by road salting as well.

Street sweeping removes about 16 percent of the phosphorus, 30 percent of the copper, 52 percent of the lead, and 46 percent of the zinc inputs to streets and parking areas. However, based on the particle size distribution of the material which the sweeper collects, only about 25 percent of the materials collected could be mobilized by stormwater runoff so the overall effectiveness of sweeping is smaller than these percentages indicate.

With respect to the materials budget, the most important point is that over 95 percent of the solids washoff load is < 500u. About 83 percent of the phosphorus, 58 percent of the copper, 37 percent of the lead and 48 percent of the zinc inputs to streets and parking areas are washed off to storm sewers on an annual basis. About 75 percent of the road salt applied to streets and parking areas is displaced to pervious areas. Eleven percent of the copper, 9 percent of the lead, and 6 percent of the zinc are resuspended and deposited on pervious areas. Resuspension of phosphorus was negligible based on snowpack data.

Pervious Areas

Pervious areas have been defined as all watershed area, either paved or unpaved, which is not directly connected to storm sewers. The materials budget for these areas is shown in Table 6-7. This area receives inputs from atmospheric deposition, traffic, domestic chemical applications, displaced road dirt, eroded soil, vegetation, animals, and roof runoff. Removals from pervious areas are by pervious runoff and disposal of vegetal matter through refuse collection. There is significant accumulation of materials on pervious areas on an annual basis.

Atmospheric deposition loads to pervious areas were based on the measured unit loads and the 386 acres of pervious area in the watershed.

Table 6-7: Pervious Area Materials Balance (Loads in Pounds)

	Total Solids	Cl	P	Cu	Pb	Zn
LOADS IN						
Precipitation	62,100	617	50.2	15.5	34.7	100
Dryfall	46,700	617	232	6.2	22.4	44.0
Traffic	60,000	---	---	69.9	667	113
Chemical Applications	63,200	---	2,530	---	---	---
Displaced Road Dirt	269,000	129,000	---	7.1	56.9	13.7
Soils	171,000	---	53.2	5.0	11.1	13.5
Roof Runoff	47,900	1,570	235	29	46.2	207
Vegetation	1,790,000	17,400	4,940	31.6	40.1	113
Animals	34,900	---	1,070	---	---	---
Total	2,540,000	149,000	8,900	164	878	605
LOADS OUT						
Pervious Runoff	510,000	743	270	20.4	247	111
Grass and Leaf Removal	1,420,000	12,600	3,640	26.6	31.8	84.1
Total	1,930,000	13,300	3,910	47	279	195
ACCUMULATION	610,000	136,000	4,990	117	599	410

Traffic solids and metal loads to pervious areas were calculated to be 67 percent of the total traffic load of these constituents as previously mentioned. It was assumed chloride and phosphorus loads from traffic were insignificant.

The total solids load attributed to soil erosion was estimated using the Universal Soil Loss Equation. An erosion load of 171,000 pounds per year was predicted based on an R value of 160, a K value of 0.37 (Markham - Ashkum - Urban soils) an LS value of 0.32 and a C value of 0.013. Constituent loads were estimated based on estimated curbside soils concentrations. These load were checked for consistency against pervious runoff loads and leachate test results and found to be reasonable.

Discussion with fertilizer companies and examination of product labels indicated that recommended nitrogen loads would be 150 pounds per acre per year and recommended phosphorus loads would be 16 pounds per acre per year. Based on these figures total watershed nitrogen loading would be 23,700 pounds and total phosphorus loading would be 2,530 pounds. Total solids loads were estimated from survey responses which indicated that forty percent of fertilizer applications are applied as liquids by lawn care companies and sixty percent are applied as solids by homeowners. Total solids loading from lawn care companies would be 40 percent of nitrogen and phosphorus loads or 10,500 pounds. Homeowner applied loads based on 27 percent nitrogen in fertilizer would be 52,700 pounds for a total solids load of 63,200 pounds. Trace metals loadings from domestic chemical applications were assumed to be negligible.

Loads from displaced road dirt were previously discussed under the materials budget for streets and parking areas.

Roof runoff loads were developed from the measured constituent concentrations presented in Chapter 5, the 31.5 inches of effective rainfall during the study year, and the estimated roof area of 65 acres tributary to pervious areas.

Based on 33 percent tree canopy and 386 acres of pervious area, there would be 127 acres of pervious area affected by leaf fall. The unit loading rate previously discussed and constituent concentrations presented in Chapter 5 were used to compute leaf fall loads to pervious areas.

Grass clipping loadings were based on the unit load and constituent concentrations previously discussed and a grassed area of 350 acres.

Virtually all animals in the watershed contribute loads to pervious surfaces. It was assumed that 72 percent of the bird, squirrel and rabbit load was deposited on pervious area based on its relative land cover percentage. Thirty-eight percent of dog and cat loads were assigned to pervious areas based on survey responses. Fifty percent of migratory bird loads were assigned to pervious areas.

Loads leaving pervious areas in runoff were determined previously for the budget around streets and parking areas.

A survey of basin residents (see Appendix A) indicated that homeowners removed 95 percent of the leaf fall and 66 percent of the grass clippings from pervious areas. These percent reductions were applied to the loads calculated previously to determine loads removed on an annual basis.

Estimated total constituent accumulation on pervious areas was calculated by subtracting outputs from inputs.

The principal source of solids to pervious areas is vegetation (75 percent). Almost all the chloride deposited in pervious areas comes from displaced road salt (87 percent). Vegetation (56 percent) and fertilizer applications (29 percent) are the principal sources of phosphorus to pervious areas. The principal copper inputs are traffic (44 percent), vegetation (20 percent), roof runoff (18 percent), and atmospheric deposition (14 percent). Seventy-seven percent of the lead loading comes from traffic with another seven percent from atmospheric deposition and seven percent from displaced road dirt. The principal zinc source to pervious areas is roof runoff (35 percent). High zinc contributions from roof runoff are probably the result of gutter deterioration. High contributions of material from roof runoff have been observed by other researchers (Pitt, 1979; Rolfe, 1975). Other important zinc sources are atmospheric deposition (24 percent), vegetation (19 percent) and traffic (19 percent).

About 22 percent of the solids input to pervious areas are transported by washoff to watershed storm sewers. Three percent of the phosphorus, 13 percent of the copper, 28 percent of the lead, and 19 percent of the zinc inputs are contributed to stormwater.

Roofs

Roofs in the Lake Ellyn watershed receive inputs from atmospheric deposition, vegetation, animals and the decomposition of construction materials such as paint, caulking, shingles, roofing nails, flashing and gutters. Materials leave roofs via roof runoff. Accumulation in gutters and on rooftops may occur if annual cleaning is not undertaken. The accumulation term in this budget includes material which might be removed by cleaning. The materials budget for roofs is shown in Table 6-8.

Atmospheric deposition loads to roofs were based on the 79.5 acres of roofs in the watershed and the unit loads measured during this study.

Leaf fall and tree detritus are the only vegetal input to roofs. Based on the information that 33 percent of the residential areas in the watershed are under tree canopy, it was calculated that 18.5 acres of the 56 acres of residential roofs were subject to leaf fall. Five percent of the commercial area is under tree canopy so this added another 1.2 acres for a total of 19.7 acres. Loads were developed using the unit loads previously discussed and concentrations presented in Chapter 5.

Animal loads were based on the loads in Chapter 5 prorated on the basis that 15 percent of the land cover in the watershed is roofs.

Materials loads from the decomposition of construction materials were obtained by the difference between other inputsand outputs plus accumulation.

Table 6-8: Roof Materials Balance (Loads in Pounds)

	Total Solids	Cl	P	Cu	Pb	Zn
LOADS IN						
Vegetation	78,800	335	112	1.2	2.0	2.6
Animals	1,800	---	59	---	---	---
Decomposition of Construction Materials	30,600	1,400	133	27.8	44.1	277
Precipitation	12,800	127	10.3	3.2	7.2	20.7
Dryfall	9,540	127	44.5	1.6	4.8	8.7
Total	134,000	1,990	359	33.8	58.1	310
LOADS OUT						
Roof Runoff to Pervious Area	47,900	1,570	235	29	46.2	207
Roof Runoff to Impervious Area	9,250	208	14.2	1.9	5.1	50.5
Roof Runoff to Storm Sewerage	9,250	208	14.2	1.9	5.1	50.5
LOADS OUT						
Total	66,400	1,990	263	32.8	56.4	308
ACCUMULATION	67,200	0	95.5	1.0	1.7	2.2

Roof runoff loads were computed using measured data. Loads were weighted by roof type on the basis of 30 percent of roofs being commercial and 70 percent being residential. Total loads were based on 31.5 inches of effective rainfall over 79.5 total acres of roofs. The distribution of loads to various control points was based on estimates of roof area tributary to these points.

Accumulation was determined by the difference between calculated roof runoff loads and input loads. It was assumed that this accumulated material was largely vegetation and vegetative constituent concentrations were assigned to the accumulated load to arrive at accumulated constituent loads.

It appears that the principal sources of solids to roofs are vegetation, the decomposition of construction materials and atmospheric deposition in that order. Chloride inputs and outputs are insignificant in terms of total chloride load applied to the watershed. It appears that resuspension of road salt or decomposition of construction materials may be the principal sources of chloride. One of the principal pigments in house paint, titanium dioxide, is manufactured using what is termed the chloride process (U.S. Environmental Protection Agency, 1974). Another potential source of chloride is from galvanized metal, since chloride is used in the zinc coating process (U.S. Environmental Protection Agency, 1973).

The principal sources of phosphorus are decomposition of construction materials, vegetation and animals. Galvanizing processes employ phosphorus compounds which may be left as a coating on gutters. Decomposition of construction materials appears to be the principal source of metals in roof runoff.

Copper, lead, and zinc are commonly used in paint production. Lead usage for architectural purposes in the last 10 years has been negligible although this material was once popular before it was banned. The 1979 consumption of zinc oxide for paint for mildew resistance was estimated at 23.9 million pounds. Consumption of phthalocyanine (cuprous chloride, urea, and phthalic anhydride) in 1979 as a pigment was 2.7 million pounds. (National Paint and Coating Association, 1982). Zinc is available from gutters, roofing nails, screens and flashing. Copper is available from flashing and as a trace contaminant in other building products. Lead is a trace contaminant in many building products including galvanized products. Based on this list of products, it is apparent that copper, lead, and zinc contributions from decomposition of building materials is not unreasonable.

Sources, Sinks and Emissions

Having constructed materials budgets around the control points in the watershed, a materials budget was constructed for the entire watershed by summing the sources, sinks, and emissions identified in these earlier budgets. The results of this summation are given in Table 6-9.

Over 1,700 tons of material are either deposited on or generated in the Lake Ellyn watershed on an annual basis. This

Table 6-9: Materials Budget -- Lake Ellyn Watershed

	Total[1] Solids	Cl[1]	P	Cu	Pb	Zn
SOURCES						
Precipitation	87.2	0.9	70.7	21.6	48.5	141
Dryfall	65.6	0.9	328	8.9	31.6	61.3
Animals	43.9	---	1,280	---	---	---
Vegetation	1,920	18.0	5,300	33.6	43.3	118
Street Salting	436	264	---	1.9	---	0.6
Paved Surface Decomposition	30.6	---	---	1.8	9.0	2.2
Traffic	90	---	---	104	1,000	170
Construction Material Decomposition	30.6	1.4	133	27.4	43.4	277
Chemical Application	63.2	---	2,610	---	---	---
Soils:						
Erosion	171	---	53	5.0	11.1	13.5
Baseflow	400	---	12	3.7	3.0	15.0
Total	3,660	285	9,780	208	1,190	799
SINKS						
Catch Basins	22.2	0.1	8.0	1.0	12.7	4.7
Street Sweeping	576	0.2	78.3	19.7	312	113
Lake Ellyn	251	-45	471	34.7	193	145
Street Dirt	10.2	---	2.9	0.3	6.6	1.5
Pervious Areas	611	136	5,200	117	599	410
Roofs	70.3	---	95.5	1.0	1.7	2.2
Grass and Leaf Removal	1,420	12.6	3,640	26.6	31.8	84.1
Total	2,960	104	9,500	200	1,160	761
EMISSIONS						
Baseflow	254	115	197	5.99	22.8	26.8
Stormflow	449	66	83.8	2.09	6.40	9.95
Total	703	181	281	8.08	29.2	36.8

[1] Load in thousands of pounds

is over 3 tons per acre per year for the 534 acre watershed. However, not all of this material reaches or passes through the lake. Source inputs must reach a point from which they can be transported by runoff or groundwater to the lake if they are to be of immediate concern. The points in an urban watershed from which this transport can occur are surfaces directly connected to storm sewers, such as streets and some roofs, the storm sewers themselves including catch basins, and the detention facility. Table 6-10 presents the summation of the materials balances around impervious areas, catch basins, and Lake Ellyn--the watershed transport system. Pervious runoff, roof runoff, and baseflow loads were allocated to the eight principal sources covered in this study. Pervious runoff loads were allocated to soils on the basis of erosion load and park soil constituent concentrations. The remaining pervious runoff loads were allocated to other sources on the basis of their annual inputs to pervious areas. Roof runoff loads were prorated to other sources based on their relative annual inputs to roofs. Baseflow loads were allocated to soils based on the constituent concentrations obtained from the soil leachate tests. Total solids load due to salt was calculated from the amount of NaCl salt needed to generate the 95,400 pounds of chloride found in baseflow. The balance of the solids were allocated to soils. The balance of constituents loads in baseflow were prorated among sources on the basis of their relative annual inputs to pervious areas. Tables 6-11 and 6-12 show the relative source contributions to the watershed as a whole and to the watershed transport system,

Table 6-10: Materials Budget Around Watershed Transport System

	Total[1] Solids	Cl[1]	P	Cu	Pb	Zn
SOURCES						
Precipitation	21.5	0.1	10.3	5.3	17.4	51.7
Dryfall	18.0	0.1	61.6	2.2	12.5	22.2
Animals	9.7	---	174	---	---	---
Vegetation	324	0.4	368	4.2	15.7	30.7
Street Salting	436	264	---	1.9	---	0.6
Paved Surface Decomposition	361	---	---	1.8	9.0	2.2
Traffic	79	---	---	43.7	535	88.1
Soils:						
Soil Erosion	171	---	53	5.0	11.1	13.5
Baseflow	400	---	12	3.7	3.0	15.0
Decomposition of Construction Materials	1	0.3	2.1	2.8	7.9	91.0
Chemical Applications	7	---	148	---	---	---
Total	1,830	265	847	71.2	611	317
SINKS						
Catch Basins	22.2	0.1	8.0	1.0	12.7	4.7
Street Sweeping	576	0.2	78.3	19.7	312	113
Lake Ellyn	251	-45	471	34.7	193	145
Street Dirt	10.2	---	2.9	0.3	6.6	1.5
Pervious Areas	269	129	---	7.2	56.9	13.7
Total	1,130	84.0	560	62.9	581	278
EMISSIONS						
Baseflow	254	115	197	5.99	22.8	26.8
Stormflow	449	66	83.8	2.09	6.40	9.95
Total	703	181	281	8.08	29.2	36.8

[1] Load in thousands of pounds

Table 6-11: Source Contributions -- Lake Ellyn Watershed

	Total Solids	Cl	P	Cu	Pb	Zn
SOURCES						
Precipitation	2	< 1	< 1	10	4	17
Dryfall	2	< 1	3	4	3	8
Animals	1	0	14	0	0	0
Vegetation	55	6	54	16	4	15
Street Salting	12	93	0	1	< 1	< 1
Paved Surface Decomposition	10	0	0	1	< 1	< 1
Traffic	3	0	0	50	84	21
Fertilizer Applications	2	0	27	0	0	0
Decomposition of Construction Materials	< 1	< 1	0	13	4	34
Soils:						
Erosion	5	0	< 1	2	1	1
Baseflow	11	0	< 1	1	< 1	2

Table 6-12: Source Contributions -- Transport System

	Total[1] Solids	Cl[1]	P	Cu	Pb	Zn
SOURCES						
Precipitation	1	0	1	7	3	16
Dryfall	1	0	7	3	2	7
Animals	< 1	0	23	0	0	0
Vegetation	18	0	43	6	3	10
Street Salting	24	> 99	0	3	0	< 1
Paved Surface Decomposition	20		0	3	1	< 1
Traffic	4	0	0	61	88	28
Decomposition of Construction Materials	< 1	0	0	4	1	29
Chemical Applications	< 1	0	17	0	0	0
Soils:						
Erosion	9	0	6	7	2	4
Baseflow	22	0	1	5	< 1	5

[1] Load in thousands of pounds

respectively.

Examination of Tables 6-9 and 6-10 reveals that only half of the solids deposited on or generated in the watershed reach the transport system. It is readily apparent that vegetation is the largest contributor of solids to the watershed. However, most of this material is either removed from the watershed by yard maintenance or retained in the soils. Only 17 percent of the vegetal load to the watershed reaches the transport system.

Another important source of solids is soils, both through erosion and baseflow. The soils load to the watershed is the same as the soils load to the transport system by definition since soils are not considered eroded until they leave pervious areas. Soils account for 31 percent of the solids entering the watershed transport system with erosion accounting for nine percent. Other important sources are street salting at 24 percent of loads to the transport system and paved surface decomposition at 20 percent.

Street salting is virtually the only source of chloride to the watershed and consequently to its transport system as well. The principal sources of phosphorus are vegetation, fertilizer applications and animals. The vast majority of the load from these sources is deposited on pervious areas. As this material accumulates, some of it is leached to shallow groundwater or eroded in pervious runoff and eventually reaches the transport system as can be seen in Table 6-12. The principal source of copper in the watershed is traffic. This traffic copper load is most likely the result of tire and brake lining wear. The decomposition of construction materials, vegetation, soils and atmospheric deposition are also important copper sources for the watershed (see Table 6-11). However, most of the loads from construction materials and vegetation are deposited to pervious areas and detained indefinitely. By far the most significant source of lead to the watershed is traffic. It appears that the major source of zinc to the watershed is the decomposition of construction materials, particularly gutters and downspouts. Much of this zinc is deposited on pervious areas by roof runoff. Other major zinc sources include traffic, atmospheric deposition and vegetation.

Sinks

Most of the solids load to the watershed is vegetal matter and as previously explained, the largest sink for solids is the removal of this material from the watershed. In terms of solids entering the transport system, major sinks include street sweeping, pervious areas, and the lake. Larger particles end up in the street sweeper and smaller particles end up in the lake. The materials stored on pervious areas are displaced road dirt and street salt which actually accumulates in shallow groundwater rather than the soil.

As previously stated, most chloride ends up on pervious areas where it it rapidly leached to shallow groundwater. The apparent production of chloride (note the "-" sign in Tables 6-9 and 6-10) by the lake is discussed in Chapter 7. The largest sinks for total phosphorus inputs are pervious areas and grass and leaf removal. In terms of total watershed inputs, pervious areas are the most important sink for metals. This is reflected in the buildup in metals concentrations in curbside soils. From the perspective of the transport system, Lake Ellyn and street sweeping are the most important sinks for metals with sweeping retaining more lead and the lake retaining more copper and zinc.

Emissions

About 19 percent of total solids input to the watershed and 38 percent of total solids input to the transport system are released in the outflow from Lake Ellyn. All of the chloride entering Lake Ellyn eventually is displaced from the lake by stormflow or baseflow. Salt is stored in the shallow groundwater under the Lake Ellyn watershed. Only three percent of the phosphorus inputs to the watershed are discharged from Lake Ellyn. However, 33 percent of the phosphorus inputs to the transport system are discharged from the lake. Most of this material is in the dissolved form and arrives at the lake via baseflow (see Chapter 7). With respect to the metals, the lake releases about four percent of the copper, two percent of the lead, and five percent of the zinc inputs to the total watershed. With respect to metals loads entering the transport system the lake releases eleven percent of copper inputs, five percent of lead inputs, and 12 percent of zinc inputs. Most of these releases are dissolved metals and this points out the high affinity of metals for soil particles and the subsequent settling of these materials to the lake bottom or their removal in street sweepings.

Source Control and Control Point Management

Having quantified the sources, sinks and emissions of constituents to the Lake Ellyn watershed as a whole, and to the system by which these materials are transported to receiving water bodies in particular, it is possible to evaluate the efficacy of source control measures and management strategies focusing on the five control points.

Source Control

The relative importance of different sources were evaluated in terms of total loads delivered to the transport system. Based on this evaluation, the potential for implementation of source controls was assessed. Table 6-13 presents the results of the source control evaluation. Rank refers to the relative importance of a source in terms of constituent contributions to the watershed transport system. Theoretical control potential is the percentage of total constituent inputs which can be controlled by eliminating all of a particular source's inputs. To be rated good, 100 percent control of a source had to eliminate 50 to 75 percent of the total constituent load. A fair rating meant 25 to 50 percent of total source inputs could be controlled. A poor rating meant less than 25 percent. An excellent rating meant that > 75 percent of total source inputs could be controlled by controlling the source being evaluated.

Actual control potential refers to the technical ability to control an individual source as well as the social acceptability

Table 6-13 -- Need and Potential for Implementation of Source Controls

Sources	Total Solids		Cl		P		Cu		Pb		Zn	
	Rank	Potential Theo/Actual	Rank	Potential Theo/Actual	Rank	Potential Theo/Actual	Rank	Potential Theo/Actual	Rank	Potential Theo/Actual	Rank	Potential Theo/Actual
Atmospheric Deposition	---	---	---	---	---	---	2	Poor/Fair	---	---	3	Poor/Fair
Animals	---	---	---	---	2	Poor/Poor	---	---	---	---	---	---
Vegetation	4	Poor/Poor	---	---	1	Fair/Poor	---	---	---	---	---	---
Street Salting	1	Poor/Poor	1	Exc/Poor	---	---	---	---	---	---	---	---
Paved Surface Decomposition	3	Poor/Fair	---	---	---	---	---	---	---	---	---	---
Traffic	---	---	---	---	---	---	1	Good/Poor	1	Exc/Poor	2	Fair/Poor
Construction Material Decomposition	---	---	---	---	---	---	---	---	---	---	1	Good/Good
Chemical Applications	---	---	---	---	3	Poor/Poor	---	---	---	---	---	---
Soils												
Soil Erosion	5	Poor/Fair	---	---	---	---	3	Poor/Fair	---	---	---	---
Baseflow	2	Poor/Poor	---	---	---	---	---	---	---	---	---	---
Total	---	Poor		Poor	---	Poor	---	Poor	---	Poor	---	Poor

of implementing control measures. This qualitative assessment is in large subjective. To be rated good 50 to 75 percent of an individual source's inputs had to be able to be controlled with known technology. A fair rating again meant 25 to 50 percent could be controlled. A poor rating meant less than 25 percent. An excellent rating meant > 75 percent could be controlled. If a technical control was assessed as being socially unacceptable, the actual control potential was rated poor regardless of the technical control ability.

The principal sources of total solids leaving the watershed are soils. Street salting, paved surface decomposition, and vegetation are also important sources of total solids. The theoretical potential for controlling these contributions is poor in all cases since each contributes less than 25 percent of total solids load. This points out the diverse nature of solids loads to the watershed transport system. The actual potential for implementation of erosion control programs was assessed as being fair. Many communities in northeastern Illinois now have sediment control ordinances. However, application of more stringent ordinances to erosion problems in mature urban areas would probably result in only a 25-50 percent reduction in total erosion loads since these areas are already well-turfed.

Repair of damaged paved surfaces can lead to a reduction in load from impervious areas. However, some of the paved surface areas are continually eroding so control would be difficult and was estimated to be fair. Social acceptability for pavement repair was assessed as being good.

Public demand for bare pavement driving conditions during snowfall precludes any reduction in salt usage although complete elimination would control virtually all solids inputs from this source. Substituting sand or cinders would greatly increase total solids loads while probably not being as satisfactory for keeping streets passable during the winter. Control of solids from vegetation was assessed as poor since leaf and grass clipping removals already occur and additional reductions in excess of 25 percent probably could not be achieved. No control of baseflow solids appears technically possible. Overall control potential for solids was rated poor due to technical and social constraints.

Street salting is virtually the sole source of chloride to the watershed, consequently theoretical control potential was rated excellent. Actual control potential was assessed as poor. Technical potential was assessed as excellent since virtually all chloride inputs could be controlled by eliminating salting but the probable public demand for safe and convenient winter driving conditions resulted in an overall poor rating.

The principal sources of phosphorus are vegetation, animals and chemical applications. Theoretical phosphorus control prospects were assessed as poor for animals and chemical applications since less than 25 percent of total loads result from either lawn and garden fertilizer usage or the watershed's animal population. Theoretical control potential for phosphorus in vegetation would be fair since 43 percent of total phosphorus inputs come from this source. Actual control potential for each of these sources was rated poor. Further control of vegetal inputs was previously assessed as being unlikely. No control over wild animals is possible. Decreases in fertilizer applications were assessed as being socially unacceptable. The overall rating for phosphorus control was assessed as poor.

Traffic soils, and atmospheric deposition have been identified as the principal sources of copper to the watershed transport system. The theoretical control potential for traffic deposition was rated good since more than 50 percent of copper loads could be eliminated through control of this source. The actual control potential for traffic deposition was rated as poor since people were not likely to abandon automobile usage within the watershed. Both theoretical and actual control of atmospheric deposition of copper was rated as poor since less than 25 percent of total copper comes from this source and actual control would be dependent on improving air quality resulting from a large and diverse population of mobile and stationary sources which is unlikely. The theoretical potential for erosion control is also poor. The actual potential for control of what copper does result from erosion has been previously discussed and rated fair. Total potential for source control of copper inputs was rated poor largely due to the inability to control traffic inputs.

Traffic is virtually the only source of lead to the watershed transport system. Actual control of traffic generated loads was previously assessed as being poor due to social limitations. Theoretically, however, if traffic related load were eliminated control would be excellent.

The principal sources of zinc to the transport system are construction material decomposition, traffic and atmospheric deposition. The theoretical control of construction material decomposition and traffic zinc would be fair (see Table 6-12). The actual control of construction material decomposition was rated as good since replacement of worn building parts, and the installation of vinyl gutters should achieve better than 50 percent reduction from this source. Social potential for achieving this source control were assessed as good assuming no significant difference in price or performance for galvanized versus vinyl gutters. Potential reduction of loads from the other sources have been previously discussed with traffic rated poor and atmospheric deposition rated fair. The overall potential for source control of this constituent was rated poor since less than 25 percent of zinc inputs could be controlled due to the diversity of zinc sources and the relative inability to control traffic and atmospheric deposition.

Control Point Management

The potential efficacy of managing each of the five control points to improve the quality of stormwater discharges was evaluated based on the materials budgets for each point.

In terms of total solids control street sweeping removes 31 percent of all solids reaching the transport system. Although this is an impressive total, the bulk of this load is particles > 500u which have no significant effect on water quality. Catch basins remove about one percent of solids entering the transport system. The lake removes about 14 percent of solids entering the transport system and releases another 38 percent (albeit largely dissolved solids). However, the lake removes about 26 percent of the total solids and 89 percent of the suspended solids entering it (see Chapter 6). Most of this load is < 500u and highly mobile. Fifteen percent of total solids loads are returned to pervious areas by wind and traffic. About 20 percent of solids reaching pervious areas is yielded to the transport system as surface runoff (see Table 6-7). Total roof runoff loads to the transport system are only one percent of total solids loads. Based on the present high levels of erosion control already in evidence in the basin and the relatively low total solids yield from roofs, it appears neither of these control points offer significant opportunity for load reduction. It appears that the control points from which total solids can be most effectively managed are the lake and street sweeping. The lake can control solids < 500u and street sweeping can control solids > 500u.

None of the control points is effective in retaining chloride. Although pervious areas accumulate over 75 percent of the chloride input to the watershed, this chloride eventually is leached to groundwater where it accumulates and finds its way to the lake via baseflow. It appears that chloride cannot be effectively managed at any control point.

Pervious areas yield about three percent of the phosphorus inputs they receive (see Table 6-7). Roof runoff contributes another 3 percent. Another 57 percent of phosphorus inputs accumulate on pervious areas but some of this finds its way into baseflow. Catch basins retain less than one percent of transport system phosphorus. Street sweeping on impervious areas removes nine percent of this phosphorus. Lake Ellyn removes 56 percent of phosphorus inputs reaching the transport system. Thirty three percent of phosphorus reaching the transport system is released from the lake.

Based on these observations it appears that the best control point at which to manage phosphorus is Lake Ellyn. Pervious areas yield very little of the phosphorus they receive but little can be done to reduce these contributions, as previously discussed. Other control points cannot significantly affect phosphorus loads.

Lake Ellyn acts to retain almost 50 percent of the copper entering the transport system. Eleven percent of copper entering the transport system leaves the lake. Pervious areas yield 12 percent of the total copper inputs they receive. As previously discussed, further improvements on this amount cannot be expected. Street sweeping removes 28 percent of copper entering the transport system. Catch basins remove only 1 percent of copper inputs. Roof runoff is responsible for only 5 percent of total transport system copper inputs. It seems that the best means for managing copper inputs is the lake. Street sweeping removes a significant amount of copper but it is doubtful whether much of this copper would be washed from the streets due to its association with larger particle sizes. Pervious areas retain a large amount of the copper they receive but they also yield a large amount of the copper load (28 percent) to the transport system (see Tables 6-7 and 6-10).

Most lead inputs to the watershed accumulate on pervious areas. About 28 percent of these inputs are washed to the watershed's transport system through surface runoff. Street sweeping removes 51 percent of lead inputs to the transport system and the lake removes another 32 percent. Catch basins retain only two percent of lead inputs. Roofs contribute only two percent of the lead to the transport system. The best place to manage lead inputs to the watershed is in the lake and on impervious areas. Although sweeping impervious areas is effective in removing total lead, it is less efficient in removing more mobile particle sizes. It is also subject to climatic interruptions since on the average it rains every four days in this region. The lake offers an excellent opportunity for lead management since 87 percent of lead entering the lake is stored in lake sediments (see Chapter 7).

Zinc inputs enter the transport system primarily through roof runoff, pervious runoff and traffic deposition. The best opportunities for controlling zinc are settling in Lake Ellyn which removes 46 percent of transport system zinc and routing directly connected downspouts to pervious areas which could remove about 32 percent of zinc inputs to the transport system. Street sweeping could also remove 36 percent of existing zinc inputs subject to the limitations previously discussed.

CHAPTER 7: DETENTION TREATMENT

Detaining water in a quiescent state promotes water quality changes by providing the time and conditions required for the relatively slow, physical and chemical aquatic reactions to take place. The physical and chemical transformations due to detention can be widely observed in nature, for example, the comparison between the influent and effluent of a wetland. Also, the associated transformations are routinely relied upon for the purification of domestic water supplies and for the treatment of domestic wastewater.

Generally, detention improves the quality of water, at least from the human perspective. The question as to whether the quality of urban stormwater can be improved by detention is trivial. The answer is yes -- this simple answer is clearly supported by field observations made during the course of this study. Determining the nature, degree and most efficient means of employing detention treatment is another matter.

Unlike water supply or domestic wastewater, urban stormwater is not a uniform, steady-state process as the previous hydrologic analyses demonstrate. It is highly variable in both quantity and quality, from one point in time to the next, and from one location to the next.

Climatic and hydrologic conditions, watershed morphology, geology, vegetal cover, and human activities all combine to produce the unique character of urban stormwater and it is this uniqueness that makes it difficult to apply the general engineering concepts to detention treatment. In developing the guidelines and recommendations contained in this report, stormwater was first characterized in terms of 15 water quality measures and potential toxic effects. Then, the transformations brought about by detention treatment, using Lake Ellyn as the case study, were evaluated. This was followed by the determination of trap efficiencies and, finally, by an assessment of detention storage requirements for given levels of protection.

Water Quality Characterization and Modification

The 15 water quality measures that were used to characterize urban stormwater runoff (including those used in calculating the materials balances) are: TSS, TDS, Hardness, Cl, COD, BOD_5, TOC, NH_4, NO_2-NO_3, P, DP, Cu, Pb, DPb, and Zn. In addition, the U.S. Environmental Protection Agency analyzed lake sediments for a number of priority pollutants -- Table 3-5 lists those pollutants that were detected. The priority pollutant program was initiated after the start of the Glen Ellyn study and was not a formal part of the evaluation. These contaminants may well affect the aquatic environment, but it is not clear, as is the case with many of the contaminants analyzed, what the extent or degree of that effect may be, since their concentrations were below toxic thresholds. However, the priority pollutants do appear to be associated with suspended material which settles, as do many of the other contaminants, to the lake bottom and thereby are immobilized. Consequently, detention treatment may well prove to be an effective control or limit on distribution of the priority pollutants in the aquatic environment.

While the main emphasis of the investigation and this report is on stormwater runoff, the other flow components, or sources of urban drainage, should not and cannot be neglected. Precipitation and baseflow both contribute quantities of contaminants and significantly affect the overall characteristics of urban water quality as demonstrated in the material budgets. For this reason, the following characterization of water quality includes precipitation and baseflow along with stormwater runoff.

In reviewing the results, it should be noted and kept in mind that the output stormflow concentrations represent displaced lake water and are not, for the most part, the results of physical or chemical reactions taking place during the storm event. None of the measured storms were of such magnitude that they exceeded the volume of water in Lake Ellyn prior to the onset of the storm. The quality of stormwater outflow reflects lake disturbances (e.g., wave action) and antecedent chemical and biological reactions and not the direct treatment of incoming stormwater.

The modification brought about by detention storage can be seen in the change in peak event mean concentrations

Table 7-1: Reduction in Peak Stormwater Concentrations Due to Detention Treatment

Constituent	Percent Reduction[1]
TSS	96
Cl	-160
COD	57
BOD_5	76
TOC	51
NH_4	-49
NO_2-NO_3	75
P	69
DP	50
Cu	54
Pb	95
DPb	-104
Zn	90

[1] Negative reduction indicates an increase

from influent to effluent (see Table 7-1). For 10 out of 13 constituents, the peak event mean concentration was reduced. This reduction ranges from a low of 50 percent for dissolved phosphorous to 96 percent for total suspended solids. For three constituents, chloride, ammonia, dissolved lead, the event mean concentration increased from influent to effluent. The reasons for these changes will be discussed later. What is of significance is that detention treatment generally reduces the potentially troublesome high constituent concentrations.

For perspective and easy review, the flow components and the associated constituent concentrations are included in a single table for each constituent (see Tables 7-2 through 7-14). The statistics are based on the study year of July 1, 1980 through June 30, 1981.

Of all the constituents, total suspended solids exhibit the greatest range in concentration, 62 mg/l to 1,032 mg/l based on event mean concentrations (see Table 7-2). The geometric mean was 196 mg/l. Total suspended solids measurement appeared to provide an adequate estimate of the undissolved material entering the lake in that the particle size distribution in suspended solids corresponded quite closely to the particle size distribution in lake sediments. The range in concentrations at the outlet is greatly reduced, 31.5 mg/l as compared to 970 mg/l. The mean storm outlet concentration was 20 mg/l. Detention, on the average, reduced the concentration of TSS by a factor of 10.

Chloride is perhaps the only constituent that showed a strong seasonal variation -- this of course because of the use of road salt. The higher concentrations appeared during snowmelt and continued on through the early spring as the winter's salt load was washed off of the streets and parkways and into the lake. The baseflow concentration of chloride is substantially greater than that for stormflow because of the predominance of snowmelt in baseflow, and the higher chloride concentrations in groundwater. Further, since most of the storms occurred during the summer period, after most of the salt had been washed out of the watershed, the geometric mean chloride concentration in stormwater was much lower, 34.7 mg/l as compared to 156 mg/l for baseflow (see Table 7-3). The significance of the chloride concentration relates to the mobilization of lead which may, under some future conditions, prove to be a problem.

The concentrations of COD are much less affected by detention than TSS under all conditions. There is a marked similarity between the concentrations of inlet and outlet baseflow and that of the water column. The outlet stormflow concentrations appear somewhat greater than the previous three but lower than the inlet stormflow concentrations, almost by a factor of 2 (see Table 7-4). Very little BOD_5 data were collected due to the problems of preservation and analysis at the low concentrations which appeared in both the influent and effluent; however, based

Table 7-2: TSS Event Mean Concentrations (mg/l)

Statistic	Precipitation	Inlet Flow		In situ	Outlet Flow	
		Base	Storm[a]		Base	Storm[a]
n	4	6	17	4	5	26
$\bar{x}$	3.0	10.0	196	20.1	13.0	19.9
s.d.	2.2	8.1	-	4.8	10.3	-
max.	6.0	25.0	1032	26.8	28.0	42.1
min.	1.0	4.0	62	15.9	1.0	10.6

[a] Geometric mean

Table 7-3: CL Event Mean Concentrations (mg/l)

		Inlet Flow			Outlet Flow	
Statistic	Precipi-tation	Base	Storm[a]	In situ	Base	Storm[a]
n	26	7	17	4	6	17
$\bar{x}$	0.26	156	34.7	85.2	139	103
s.d.	0.13	21.5	-	58.0	76.6	-
max.	0.63	190	86	170	650	224
min.	0.07	130	8	38.7	76	57.5

[a] Geometric mean

TABLE 7-4: COD Event Mean Concentrations (mg/1)

Statistic	Precipitation	Inlet Flow Base	Inlet Flow Storm[a]	In situ	Outlet Flow Base	Outlet Flow Storm[a]
n	10	6	15	4	6	15
$\bar{x}$	5.10	38	91.5	37.5	33	42.3
s.d.	2.77	27	-	7.9	23	-
max.	11.3	83	346	46.7	68	149
min.	2.50	11	33	28.1	10	14

[a] Geometric mean

Table 7-5: BOD_5 Event Mean Concentrations (mg/l)

		Inlet Flow			Outlet Flow	
Statistic	Precipitation	Base	Storm[a]	In situ	Base	Storm[a]
n	n.d.	1	3	4	1	3
$\bar{x}$		2.7	18	13	9.1	7
s.d.			-	5		-
max.			51	20		12
min.			6	8		4

[a] Geometric mean

on the available data, a modest reduction in BOD_5 concentrations in outlet flows as opposed to inlet was observed (see Table 7-5). Still, in situ concentrations differed little from the mean inlet stormflow concentrations which, holding to the theory that outlet stormflow is simply displaced lake water, would indicate little change in BOD_5 concentrations due to detention. Nevertheless, an important difference between inflow and outflow concentrations of BOD_5 and COD is the difference in maximum event mean concentrations, the maximum inflow being 51 mg/l for BOD_5 and 346 mg/l for COD while the maximum outflow was 12 mg/l for BOD_5 and 149 mg/l for COD. As will be discussed later, detention storage does not greatly reduce the overall BOD_5 or COD loads but it does appear to redistribute it and maintain concentrations of BOD_5 and COD at levels protective of downstream waters -- the discharge from the lake, in terms of BOD_5, is similar to the effluent of an advance secondary treatment plant. Phytoplankton are present in the lake and this along with wave disturbance limits the reduction of BOD_5. A similar situation exists with TOC. Some organic carbon is being deposited resulting in a modest reduction in TOC load. The change between inlet and outlet peak concentrations, however, is more significant (see Table 7-6). Again, the similarity between baseflow and outlet concentrations supports the theory of displacement as opposed to treatment and discharge.

The behavior of ammonia concentrations is quite different

Table 7-6: TOC Event Mean Concentrations (mg/l)

		Inlet Flow			Outlet Flow	
Statistic	Precipitation	Base	Storm[a]	In situ	Base	Storm[a]
n	10	6	14	n.d.	5	13
$\bar{x}$	1.51	4.4	15.2		9.0	9.2
s.d.	0.55	4.0	-		9.3	-
max.	2.6	12.6	28.0		14.0	13.6
min.	0.8	2.2	8.0		5.3	6.9

[a] Geometric mean

Table 7-7: NH_4 Event Mean Concentrations (mg/l)

		Inlet Flow			Outlet Flow	
Statistic	Precipitation	Base	Storm[a]	In situ	Base	Storm[a]
n	27	6	18	4	6	18
$\bar{x}$	0.42	0.13	0.18	0.40	0.41	0.20
s.d.	0.26	0.06	-	0.33	0.51	-
max.	1.00	0.20	0.83	0.88	1.30	1.24
min.	0.09	0.04	0.02	0.19	0.02	0.08

[a] Geometric mean

Table 7-8: NO_2-NO_3 Event Mean Concentrations (mg/l)

Statistic	Precipitation	Inlet Flow		In situ	Outlet Flow	
		Base	Storm[a]		Base	Storm[a]
n	29	7	18	4	5	18
$\bar{x}$	0.51	1.11	0.77	0.13	0.05	0.10
s.d.	0.29	0.22	-	0.10	0.05	-
max.	1.69	1.40	1.52	0.28	0.11	0.46
min.	0.22	0.80	0.47	0.06	0.01	0.04

[a] Geometric mean

than that of most other constituents. Precipitation, in situ and outlet baseflow concentrations are quite similar while storm inlet and outlet concentrations are similar, although not greatly different from the others. The higher concentrations of ammonia in the baseflow may be due to a higher percentage of flow coming from the submerged outlet which draws water from the lower layers of the lake where anoxic conditions are common (see Table 7-7). NO_2-NO_3 concentrations, on the other hand, are quite high in precipitation and inlet baseflow (see Table 7-8). They are somewhat lower in inlet stormflow and much lower in situ and in both outlet baseflow and stormflow. Deposition, chemical reduction, and algal uptake of NO_2-NO_3 are undoubtedly the main cause for this difference. Detention strongly influences NO_2-NO_3 but has no beneficial effect on NH_3.

P behaves in a somewhat similar fashion to total suspended solids except that the inlet baseflow concentrations are very similar to the inlet stormflow concentrations (see Table 7-9). In situ and both outlet baseflow and stormflow concentrations are very similar. P concentrations in precipitation are markedly lower. DP concentrations, on the other hand, are high only in inlet baseflow. All other concentrations appear to be quite similar and substantially less. In fact, outlet stormflow concentrations are very similar to precipitation concentrations. Again, the displacement theory explains the similarity between in situ

Table 7-9: P Event Mean Concentrations (mg/l)

		Inlet Flow			Outlet Flow	
Statistic	Precipitation	Base	Storm[a]	In situ[b]	Base	Storm[a]
n	8	7	17	4	6	17
$\bar{x}$	0.03	0.49	0.48	0.20	0.16	0.20
s.d.	0.01	0.11	-	0.04	0.16	0
max.	0.05	0.61	1.01	0.24	0.45	0.31
min.	0.01	0.36	0.19	0.14	0.05	0.13

[a] Geometric mean

[b] Total PO_4

Table 7-10: DP Event Mean Concentrations (mg/l)

		Inlet Flow			Outlet Flow	
Statistic	Precipitation	Base	Storm[a]	In situ	Base	Storm[a]
n	8	7	16	4	5	16
$\bar{x}$	0.03	0.24	0.08	0.05	0.06	0.03
s.d.	0.01	0.05	-	0.04	0.07	-
max.	0.05	0.31	0.18	0.10	0.17	0.09
min.	0.01	0.18	0.01	0.02	0.01	0.01

[a] Geometric mean
[b] Dissolved PO_4

and outlet concentrations. Also, some DP undoubtedly was lost to algae and ultimately released from the lake, unmeasured, in the form of suspended solids.

Cu, Pb and Zn concentrations, at least in their total form, are similar to each other in most every respect. Inlet stormflow concentrations are high. Outlet stormflow concentrations are greatly reduced, approximately by an order of magnitude. Their outlet stormflow concentrations are similar to their outlet baseflow concentrations. Further, the concentration of these metals found in precipitation is quite similar to the concentration found leaving Lake Ellyn (see Tables 7-11, 7-12 and 7-14). However, DPb (the dissolved components of Cu and Zn are not reported in that their observed concentrations are subject to doubt due to detection limits) behave somewhat differently than total Pb (see Table 7-13). Inlet baseflow and stormflow concentrations are somewhat similar to outlet baseflow concentrations while outlet baseflow concentrations are 4 to 5 times greater. Outlet stormflow concentrations and precipitation concentrations are quite similar. The elevated outlet stormflow concentrations appear to be due to the interaction of Cl and Pb. The correlation between the two is quite strong as will be dicussed later.

As mentioned earlier, Cl was the only constituent that exhibited a strong seasonal variation. This variation, of course, is also reflected in the associated measure, and

Table 7-11: Cu Event Mean Concentrations (mg/l)

		Inlet Flow			Outlet Flow	
Statistic	Precipitation	Base	Storm[a]	In situ	Base	Storm[a]
n	24	7	16	4	6	16
$\overline{x}$	0.006	0.006	0.041	0.010	0.004	0.006
s.d.	0.006	0.003	-	0.004	0.002	-
max.	0.021	0.010	0.112	0.016	0.007	0.008
min.	0.001	0.002	0.019	0.007	0.002	0.005

[a] Geometric mean

Table 7-12: *Pb* Event Mean Concentrations (mg/l)

Statistic	Precipitation	Inlet Flow		In situ	Outlet Flow	
		Base	Storm[a]		Base	Storm[a]
n	28	6	14	4	6	14
$\bar{x}$	0.014	0.005	0.224	0.11	0.012	0.024
s.d.	0.009	0.003	–	–	0.013	–
max.	0.038	0.011	0.974	–	0.038	0.046
min.	0.002	0.002	0.046	–	0.003	0.006

[a] Geometric mean

Table 7-13: DPb Event Mean Concentrations (mg/l)

		Inlet Flow			Outlet Flow	
Statistic	Precipitation	Base	Storm[a]	In situ	Base	Storm[a]
n	30	6	13	4	6	13
$\bar{x}$	0.011	0.002	0.004	0.11	0.003	0.016
s.d.	0.008	0.004	–	–	0.003	–
max.	0.038	0.009	0.028	–	0.008	0.057
min.	0.002	0.000	0.001	–	0.001	0.001

[a] Geometric mean

Table 7-14: Zn Event Mean Concentrations (mg/l)

Statistic	Precipitation	Inlet Flow		In situ	Outlet Flow	
		Base	Storm[a]		Base	Storm[a]
n	29	7	17	4	6	17
$\bar{x}$	0.051	0.024	0.171	0.028	0.019	0.028
s.d.	0.034	0.015	-	0.012	0.012	-
max.	0.127	0.040	0.605	0.045	0.030	0.060
min.	0.019	0.010	0.062	0.015	0.010	0.015

[a] Geometric mean

total dissolved solids (see Table 7-15). Most of the other measures remained reasonably constant from one season to the next over the sampling year. The variations that do occur are difficult to explain. Both ammonia and nitrite concentrations appear to be higher in the winter as opposed to the other seasons, although not greatly different. This might be explained by the lack of algal activity in the winter, but more likely than not it is due to a greater quantity of water coming from the submerged outlet in the winter; and, consequently, the variation is only significant in terms of the operation of the lake. The metals tend to fall from summer to fall to winter and then increase in concentration again in the spring. The trend is not particularly strong and given only one year of data, it is not reasonable to assume there is a seasonal trend. It should be emphasized that the data are for a single year and that little can be said with confidence about seasonal trends using such limited information.

Constituent Prediction

Characterizing urban stormwater runoff short of making field measurements, is not well justified based on the results of the Glen Ellyn study. The relationship between flow and the concentration of constituent is nearly nonexistent for both inflow and outflow even when the independent variables are event mean concentrations, which include a component of flow (see Table 7-16). TOC

Table 7-15: Inlet Stormflow Mean Concentrations by Season[1]

Constituent	Summer		Fall		Winter		Spring	
	n	mg/l	n	mg/l	n	mg/l	n	mg/l
TSS	6	196	3	221	2	284	15	287
TDS	7	182	3	211	2	772	14	253
Hardness	6	49.3	3	57.3	2	306	14	69.4
Cl	6	26.3	3	59.3	2	107	14	41.1
COD	6	115	3	106	2	114	11	112
TOC	3	11.5	2	12.5	2	16.9	14	18.9
NH4	6	.213	3	.253	2	.360	15	.195
NO2-NO3	6	.763	3	.617	2	1.03	15	.781
P	5	.402	3	.527	2	.375	15	.564
DP	5	.080	3	.123	2	.155	14	.080
Cu	6	.0448	2	.0425		n.d.	14	.048
Pb	5	.316	2	.147	2	.044	13	.296
DPb	5	.0074	2	.017	2	.010	11	.0046
Zn	6	.197	3	.185	2	.178	14	.222

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[1] Arithmetic means for study year

Table 7-16: Correlation Coefficient -- Storm Volumes vs. Event Mean Concentrations

Constituent	Coefficient Inflow	 Outflow
TSS	-0.0405	0.0644
TDS	0.141	0.0562
Hardness	0.258	0.211
Cl	0.0433	0.0335
COD	-0.353	-0.0600
TOC	-0.302	-0.654
NH_4	0.0229	-0.0375
NO_2-NO_3	0.321	0.144
P	-0.126	0.189
DP	0.259	0.212
Cu	-0.0341	0.355
Pb	-0.156	0.028
DPb	-0.371	-0.172
Zn	-0.226	0.217

concentrations at the outlet exhibit the highest correlation, and the only one that was significant although negative. i.e., lower concentrations associated with higher flows. DP and NO_2-NO_3 concentrations appear to increase with increasing flow but, again, their correlation coefficients are not significant, at least not at the five percent confidence level. Correlation coefficients were also computed for peak flows and event mean concentrations with similar results. Consequently, flow is not a good indicator of water quality.

It is unfortunate that flow is not a good predictor because of the relative abundance of flow as compared to water quality measurements. Further, there is, unfortunately, no single parameter found among the observations at Lake Ellyn that might serve to adequately predict the other constituents of interest. In terms of defining input concentrations, the best parameters appear to be TSS, Pb and Cu (see Table 7-17). Out of 14 constituents, TSS might be used to estimate six, as can lead or copper. P, a fourth candidate, can be used to estimate five. The exceptions to such a procedure would be NO_2-NO_3, and DPb lead, which do not show a good correlation with any of the other constituents. Consequently, to characterize the quality of runoff, it may be necessary to undertake some field measurements for each study area. In terms of treatment design, sampling may be required, at any rate, to assess the settleability and unique conditions

Table 7-17: Significant Correlations of Inlet Constituent Concentrations[a]

Constituent	TSS	Cl	P	DP	Cu	Pb
TSS	1.0		.58		.85	.81
TDS		.85		.72		
Hardness		.83		.76		
Cl		1.0		.88		
COD			.68		.75	.73
TOC	.70					
NH_4	.70				.66	.55
NO_2-NO_3						
P	.58		1.0		.73	.74
DP		.88		1.0		
Cu	.85		.74		1.0	.99
Pb	.81		.74		.99	1.0
DPb						
Zn	.7[illegible]		.72		.97	.97

[a] Event means for study year excluding snowmelt

which may disrupt the detention treatment process.

Predicting the qualitative characteristics of water leaving the treatment process may be even more difficult. Based on the Lake Ellyn experience, only Cl, Pb and DPb can serve to estimate the concentrations of effluent constituents. In this case, TSS is totally inadequate (see Table 7-18). Chloride can be used to estimate seven and lead six. Surprisingly, DPb correlates quite well with 8 constituents. The correlation of DPb with Cl, as previously noted, is quite high under effluent conditions and nonexistent under influent conditions reflecting the possible in situ Cl-Pb reaction within the lake. The low concentrations and the complex biological and chemical reactions seem to thwart simple effluent relationships.

While predicting constituent concentrations from other constituents or by means of flow does not appear to be particularly promising, once given a set of water quality characteristics or concentrations, the prediction of extreme events can be accomplished with some confidence. All of the constituent concentrations used to characterize urban stormwater, which were discussed above, conform and can be characterized by the lognormal probability distribution. The parameters for this distribution, by season and constituent are given in Tables 7-19 through 7-22. Using these distributions, the magnitude and probability of extreme events can be defined. The probability is of course conditional on the occurrence of

Table 7-18: Significant Correlations of Outlet Constituent Concentrations[a]

Constituent	TSS	Cl	P	Cu	Pb	DPb
TSS	1.0	.62				
TDS		.94			.77	.74
Hardness		.68				.65
Cl	.62	1.0			.81	.77
COD						.67
TOC		-.72		.68	-.95	-.76
NH_4						
NO_2-NO_3			.58			
P			1.0			
DP						
Cu						
Pb		.81			1.0	.87
DPb		.77			.87	1.0
Zn	.65	.75				.59

[a] Event means for study year excluding snowmelt

Table 7-19: Lognormal Distribution Parameters/Summer

Constituent[1]	n	$\bar{x}$	s.d.
Inflow			
TSS	6	5.15	0.556
TDS	7	5.02	0.681
Hardness	6	3.82	0.444
Cl	6	2.81	1.22
COD	6	4.64	0.506
TOC	3	2.44	0.131
NH_4	6	-1.57	0.262
NO_2-NO_3	6	-0.300	0.275
P	5	-0.963	0.393
DP	5	-2.88	0.998
Cu (ug/l)	6	3.77	0.281
Pb (ug/l)	5	5.65	0.496
DPb (ug/l)	5	1.96	0.329
Zn (ug/l)	6	5.22	0.392
Outflow			
TSS	5	2.65	0.236
TDS	6	5.93	0.120
Hardness	5	4.90	0.099
Cl	5	4.35	0.246
COD	5	3.94	0.375
TOC	3	2.20	0.002
NH_4	5	-0.705	0.577
NO_2-NO_3	5	-2.10	0.894
P	4	-1.50	0.145
DP	4	-3.48	0.865
Cu	5	-5.23	0.252
Pb	4	-3.89	0.259
DPb	4	-4.24	0.423
Zn	5	-3.82	0.245

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[1] mg/l except where noted

Table 7-20: Lognormal Distribution Parameters/Fall

Constituent (mg/l)[1]	n	$\bar{x}$	s.d.
Inflow			
TSS	3	5.25	0.640
TDS	3	5.33	0.235
Hardness	3	4.02	0.279
Cl	3	4.04	0.374
COD	3	4.63	0.302
TOC	2	2.51	0.200
NH_4	3	-1.60	0.800
NO_2-NO_3	3	-0.543	0.438
P	3	-0.668	0.285
DP	3	-2.10	0.122
Cu (ug/l)	2	3.72	0.322
Pb (ug/l)	2	4.96	0.374
DPb (ug/l)	2	2.56	1.09
Zn (ug/l)	3	5.04	0.799
Outflow			
TSS	2	2.78	0.404
TDS	2	6.04	0.187
Hardness	2	5.06	0.110
Cl	2	4.43	0.370
COD	2	3.84	0.177
TOC	1	2.21	
NH_4	2	-2.2	0.335
NO_2-NO_3	2	-2.71	0.025
P	2	-1.77	0.018
DP	2	-3.75	0.148
Cu	1	-5.40	
Pb	1	-3.37	
DPb	1	-3.72	
Zn	2	-3.83	0.539

[1] mg/l except where noted

Table 7-21: Lognormal Distribution Parameters/Winter

Constituent[1]	n	$\bar{x}$	s.d.
Inflow			
TSS	2	5.65	0.057
TDS	2	6.60	0.428
Hardness	2	4.67	0.04
Cl	2	5.45	1.10
COD	2	4.88	0.219
TOC	2	2.83	0.025
NH_4	2	-1.35	1.21
NO_2-NO_3	2	0.029	0.041
P	2	-0.98	0.132
DP	2	-1.89	0.325
Cu (ug/l)	n.d.		
Pb (ugl)	2	3.78	0.064
DPb (ug/l)	2	2.22	0.599
Zn (ug/l)	2	5.16	0.310
Outflow			
TSS	2	1.92	0.359
TDS	2	6.69	0.071
Hardness	2	5.32	0.192
Cl	2	5.64	0.092
COD	2	3.76	0.130
TOC	2	1.98	0.031
NH_4	2	-1.91	0.558
NO_2-NO_3	2	-1.99	0.308
P	2	-2.17	0.186
DP	2	-3.02	0.694
Cu	2	-4.95	0.490
Pb	2	-4.97	0.203
DPb	2	-4.97	0.203
Zn	2	-0.220	5.02

[1] mg/l except where noted

Table 7-22: Lognormal Distribution Parameters/Spring

Constituent[1]	n	$\overline{x}$	s.d.
Inflow			
TSS	15	5.36	0.783
TDS	14	5.40	0.542
Hardness	14	4.17	0.395
Cl	14	3.502	0.716
COD	11	4.37	0.946
TOC	14	2.82	0.507
NH_4	15	-2.04	0.950
NO_2-NO_3	15	-0.36	0.549
P	15	-0.74	0.653
DP	14	-2.84	0.937
Cu (ug/l)	14	3.69	0.598
Pb (ug/l)	13	5.28	0.978
DPb (ug/l)	11	1.11	0.872
Zn (ug/l)	14	5.18	0.688
Outflow			
TSS	10	3.20	0.404
TDS	10	6.06	0.264
Hardness	10	5.10	0.089
Cl	10	4.82	0.472
COD	8	3.60	0.664
TOC	9	2.22	0.279
NH_4	11	-1.89	0.352
NO_2-NO_3	11	-2.31	0.759
P	11	-1.62	0.237
DP	10	-3.44	0.495
Cu	10	-5.02	0.144
Pb	9	-3.68	0.808
DPb	8	-4.12	1.58
Zn	10	-3.42	0.440

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[1] mg/l except where noted

an event. This is to say that given a constituent and concentration of interest (e.g., the 96-hour LC-50 concentration) the lognormal probability function can be used to calculate the probability of its occurrence given a stormwater event. The ability to estimate this probability enables the determination of risk as will be discussed in the next section.

Toxicity and Risk

The definition of risk has two components: the magnitude of the event which is to be avoided and the probability of its occurrence. From a water quality viewpoint, the event that is to be avoided is simply the event that impairs a beneficial use. In the extreme, it may be the event that causes a fish kill or greatly disrupts aquatic life. On the other hand, it may simply be an event that exceeds a chemical condition which debilitates rather than annihilates the desirable life. In regard to the first case, lethal concentrations of toxicants entering Lake Ellyn were not observed during the study period. Unionized ammonia, NH_3, which is commonly identified as a major toxicant contributed by point sources, was always below lethal concentrations. Under a rather conservative conditions (75 percent oxygen saturation) the 96-hour LC50 concentration for the unionized fraction of total ammonia is 1.94 mg/l (see Table 7-23). There was not an event mean concentration (stormflow inlet or outlet or baseflow inlet or outlet) for which total ammonia exceeded this

Table 7-23: Constituent Toxicity[1]

Dissolved Metal	96-LC50	Natural log (96-LC50)	Component Toxicity[2]	Component Concentration	Natural log (Component Concentration)
NH_3[3] (ug/l)	1.94	0.662	.05	.0970	-2.33
Cu (ug/l)	574	6.35	.05	28.7	3.36
Pb (ug/l)	3020	8.01	.05	151	5.02
Zn (ug/l)	1810	7.50	.05	90.5	4.50

[1] Assuming 25 mg/l hardness, 75 percent oxygen saturation, 21° celsius, pH 8.6
[2] Based on bluegill maintenance (Herbert, 1965)
[3] Unionized

concentration for whatever duration. A similar situation existed for the other potential toxicants: Pb, Cu and Zu. Their 96-hour LC50's were computed again based on rather conservative assumptions (25 mg/l hardness, 75 percent oxygen saturation) and they are reported in Table 7-23. Further, these lethal conditions are for the bio-available metal which, more than likely, would be the dissolved state. Nevertheless, the observed total Cu concentration (suspended and dissolved) were well below the lethal conditions for all flow components inlet and outlet. A similar situation exists for both Pb and Zn (see Table 7-23 in association with Tables 7-11, 7-12 and 7-14). One further comment should be made in regard to the 96-hour LC50 values. The lethal concentrations are by definition relative to 96 hours of exposure. The exposure time during a storm event, on the average, will not exceed 5.6 hours. The longest observed duration was approximately 12 hours

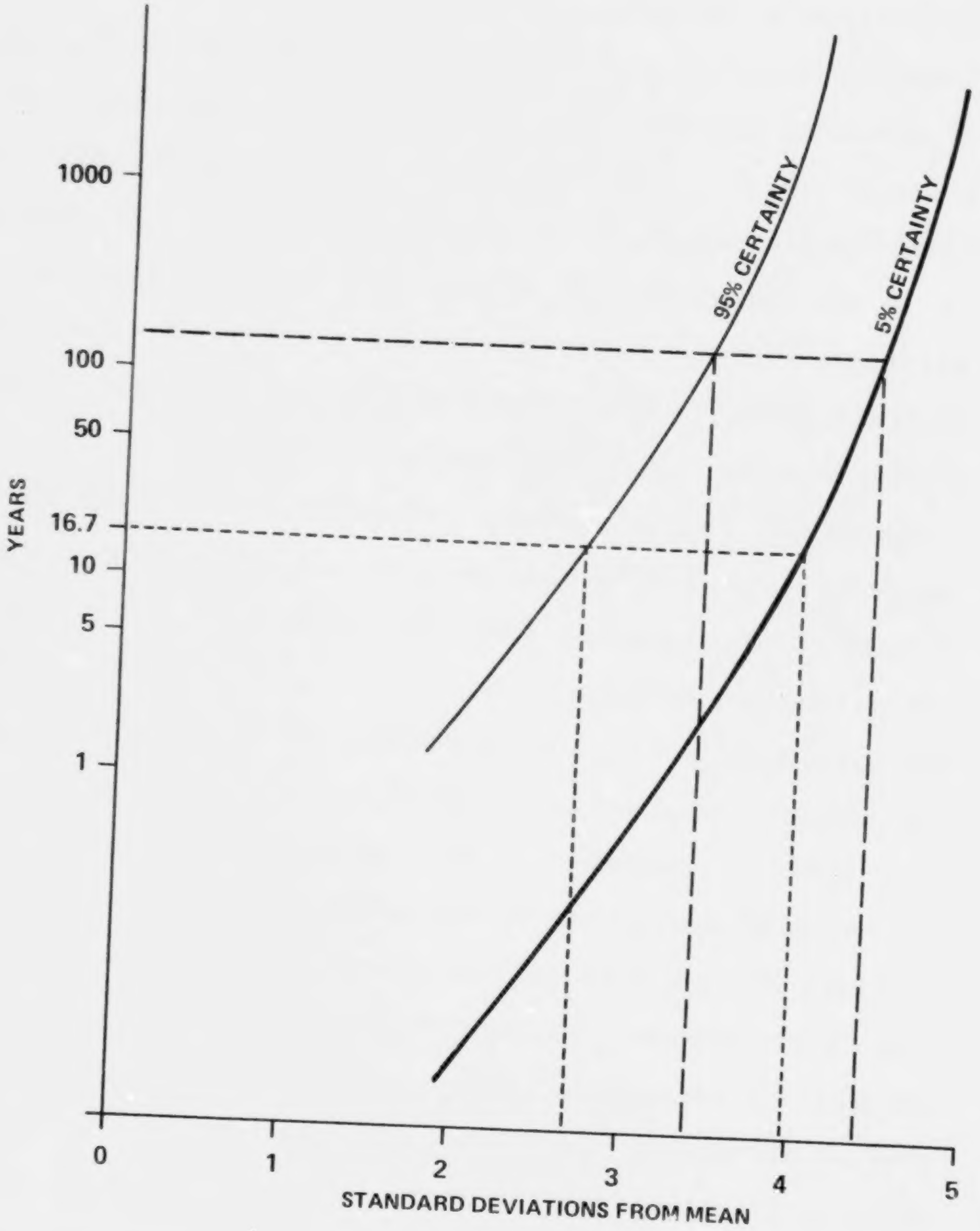
Maintaining a healthy environment, of course, requires not only the avoidance of lethal conditions but also the avoidance of those conditions which stress the aquatic community leading to disease and a debilitated state. This latter environmental definition is more difficult to specify, but recent work done by the Illinois Natural History Survey (Sparks, 1976) offers a workable definition. This definition is termed the "bluegill toxicity index". It involves calculating the components of toxicity (e.g., heavy metals, ammonia, etc.) and summing them to produce an aggregate index value, assuming that the toxicity components are cumulative and not synergestic, although dissolved oxygen, temperature, pH and hardness play a direct role in the calculation of the index. In the application of this definition to streams and lakes in northeastern Illinois, investigators have found that a bluegill toxicity unit of 0.2 is adequate for the survival of a healthy bluegill type fish population (Brigham, 1982, Dreher, 1980). The interpretation of this level of toxicity, in regard to the following analysis, is that if it is not exceeded, the aquatic life is not threatened or stressed. In reality, for short periods of time, the bluegill toxicity level of 0.2 may well be exceeded without unduly harming the aquatic community (Brigham, 1982).

Taking the four previously identified toxic constituents (NH_3, Pb, Cu and Zn) and allocating .05 toxic units to each results in a component toxicity concentration 95 percent lower than the 96-hour LC50. The component concentrations are listed in Table 7-23. The component toxicity is simply the measured constitutent concentration divided by the 96-hour LC50. Consequently, the component concentration is 96-hour LC50 multiplied by the component toxicity.

Figure 7-1 relates the component concentration to the risk of occurrence. As the component concentration exceeds the mean by successive numbers of standard deviations, the risk of occurrence deminishes. For example, the unionized ammonia component concentration 0.0970 mg/l, given in the

FIGURE 7-1: RISK OF TOXIC CONCENTRATION EXCEEDANCE

IF REFERENCE VALUE (e.g. 96 . LC 50) IS GREATER THAN......



* ASSUMING 60 EVENTS/YEAR

previous test conditions would be contained in 0.582 mg/l total ammonia. This concentration is approximately 3.9 standard deviations to the right of the mean summer conditions (see Table 7-19). There would be little more than a five percent chance in 10 years of this happening. This assumes 60 events in a year which, of course, covers the entire year and not just the summer when the critical conditions would likely occur). If this concentration were exceeded, to a minor extent, lethal conditions would not result. At most chronic conditions would result and then only if concurrent heavy metal toxicity components were of equivalent magnitude -- as previously indicated, there is not a correlation between NH_4 and the heavy metals consequently the probability of toxic stress is even more remote.

A similar example can be constructed for DPb, but rather than on the influent concentrations, on the effluent concentrations since they reflect more hostile or toxic conditions. In this case, the component concentration for lead would be 151 mg/l. This is approximately 5.6 standard deviations from the mean summer conditions indicating only a five percent chance of occurrence in over 1000 years (see Figure 7-1).

In summary, the risk of toxic events resulting from urban stormwater washoff are remote at best. Toxic conditions within and leaving Lake Ellyn appear to be highly unlikely. Further, at least in regard to the bluegill toxicity index, the acceptable level of 0.2 blue gill toxicity units would be exceeded only under very infrequent circumstances. The presence of bluegill, sunfish and other fish species in Lake Ellyn would seem to attest to this. If there is a relationship between the quality of aquatic life and the chemical characteristics of urban stormwater runoff (both dissolved or suspended), it occurs at a sublethal level and it may well be impossible to define because of the many other interactions affecting the aquatic populations. The physical constraints of the aquatic environment (e.g., depth, substrate material, food sources and spawning areas) as well as interspecies competition (e.g., the destruction of bass spawning areas by carp may be more important). Consequently, given the careful design of a detention facility, reasonable, acceptable aquatic life should be able to survive at least in terms of water chemistry.

Trap Efficiency

While it is important for the control technology (in this case detention treatment) to buffer the downstream waters from toxic concentrations of contaminants leaving the urban watershed, it is also important that the control reduce the absolute quantities of materials leaving the watershed and moving downstream. As previously noted urban stormwater runoff has both long-term and short-term affects. The load reduction pertains to the long-term effects while the previous discussion provided some arguments to indicate that detention treatment can indeed buffer the stream from short-term toxic conditions. The purpose of this section is to demonstrate the benefits of detention treatment on controlling total loads.

Based on the material budgets constructed, and presented in Chapter 5, the mass of materials entering the lake during the study period are reported in Table 7-24. In a similar fashion, the mass of constituents discharged from Lake Ellyn are given in Table 7-25. These input and output loads were used to calculate the trap efficiency of Lake Ellyn in two ways. The first was to calculate the trap efficiency on a storm event-by-storm event basis. This measure of trap efficiency ignores the quantity of constituent leaving the lake during baseflow periods -- which would have occurred under natural conditions at any rate. The other efficiency measure was calculated by comparing the total load in to the total load out. Both efficiency measures were calculated by subtracting output load from input load and dividing the difference by the total input load (see Table 7-26). The first item of note is the negative trap efficiencies calculated for chloride, ammonia and dissolved lead. In the case of chloride, Lake Ellyn is purged of this constituent during the spring and summer; however, it would be expected that the long-term, annual trap efficiency should be zero and certainly not negative. The negative trap efficiency reported for the study year is due to, in part, a carry over from the

Table 7-24: Detention Basin Input Loads (pounds/study year)

Constituent	Inlet Storm Load	Inlet Base Load	Precip-tation Load	Dry Atmospheric Load	Total
TSS	184000	6120	214	33	190000
Cl	40800	95400	16	16	136000
COD	87100	23200	356	396	111000
BOD_5	16600	1840	n.d.	n.d.	18400
TOC	13100	2690	101	36	15900
NH_4	163	79.5	27.7	7.7	278
NO_2-NO_3	669	679	35.7	8.4	1390
P	402	300	1.34	5.60	709
DP	67.9	147	1.34	0.49	217
Cu	38.2	3.7	0.37	0.15	42.4
DCu	7.17	2.45	0.30	0.07	9.99
Pb	217	3	0.85	0.58	221
DPb	5.39	1.22	0.69	0.04	7.34
Zn	163	15	2.63	1.13	182
DZn	31.3	3.1	2.62	0.77	34.8

Table 7-25: Detention Basin Output Loads (pounds/study year)

Constituent	Outlet Storm Load	Outlet Base Load	Total
TSS	18200	5760	24000
Cl	115000	66000	181000
COD	43700	17300	61000
BOD_5	6970	6810	13800
TOC	8970	4710	13700
NH_4	276	159	435
NO_2-NO_3	107	26.2	133
P	197	83.8	281
DP	30.2	31.4	61.6
Cu	5.99	2.09	8.08
DCu	4.26	1.57	5.83
Pb	22.8	6.40	29.2
DPb	15.4	1.57	17.0
Zn	26.8	9.95	36.8
DZn	8.88	3.14	12.0

Table 7-26: Trap Efficiency

Constituent	Storm[a]	Study Year[b]
TSS	0.90	0.87
Cl	-1.82	-0.33
COD	0.50	0.45
BOD_5	0.58	0.25
TOC	0.32	0.14
NH_4	-0.69	-0.56
NO_2-NO_3	0.84	0.90
P	0.51	0.60
DP	0.56	0.72
Cu	0.84	0.81
Pb	0.89	0.87
DPb	-1.86	-1.32
Zn	0.84	0.78

[a] Based on 14 measured events and a total of 91 storm events
[b] July 1, 1980 through June 30, 1981

previous year an insufficient low-flow measurements of chloride entering the lake during snowmelt and early spring runoff. The apparent production of ammonia and hence the negative trap efficiency is due to anoxic conditions at the lake bottom and the associated reduction of organics. On the other hand, lead deposited with the settleable solids appears to be complexing with chloride during the winter and spring increasing dissolved lead concentrations and the load leaving the lake.

The organics (BOD_5 and TOC) are not readily trapped by the lake, this is somewhat of a disappointing result; nevertheless, their concentrations are generally reduced alleviating a part of the urban stormwater problem. The indicated trap efficiency for BOD_5 is very close to the required reduction, estimated during the 208 program, for the control of nonpoint sources, in order to meet instream water quality criteria (e.g., dissolved oxygen). On the other hand, the storm trap efficiency, for BOD_5 is at the upper limit of the estimated required control for nonpoint sources in new areas. It would appear within this range that the objectives of the 208 plan, in terms of BOD_5 loadings, could be met with detention treatment. However, in the case of the organic constituents and ammonia, a note of caution must be sounded. Given the delicate balance between nutrients and biological reactions, the improper operation and management of a detention facility could produce these constituents in such proportions that the benefits of detention treatment would be out weighed. In this region, there are example of detention facilities which have matured to the point that the facilities are autotropic creating a greater BOD_5 load on the stream than they remove (Northeastern Illinois Planning Commission, 1979).

In the case of both phosphorous and dissolved phosphorous, the trap efficiency is much better on the annual basis than for the storm event basis. Part of the trap efficiency results from both constituents being tied up by phytoplankton and other plant life and then later being released in other chemical forms. In the case of phosphorous, for example, suspended phosphorous is being deposited while part of the dissolved phosphorous is leaving the lake, unmeasured as dissolved, in suspended algal material, as previously maintained. The heavy metals except, of course, for dissolved lead are substantially reduced with reasonably high trap efficiencies for both measures, storm and annual.

Design Considerations

The design of a detention facility should address two concerns. The first is that the facility adequately trap urban stormwater constituents and modify the concentration of contaminants in order to protect the downstream water resources. The second is to attempt to satisfy recreational aesthetic and environmental objectives of the community. Lake Ellyn is a classic example of where these two sets of conditions have been satisfied. As was previously noted, trap efficiencies are high and in regard to almost every water quality measure, concentrations of contaminants are substantially reduced as urban stormwater moves through Lake Ellyn. On the other hand, the lake is extensively used by the surrounding community and viewed as an asset to the community. Consequently, the lake is well maintained as are the surrounding lands.

There are four features of the lake which make it a good control device:

1. The mean detention time of the lake is substantially greater than required for sedimentation of urban stormwater waste. Related to this, the lake provides approximately one inch of storage for the tributary area which, given the local hydrology, results in a mean detention time of 265 hours. Given this and the fact that only a four hour settling time is required to remove 95 percent of the incoming suspended solids yields ample detention time.
2. The main inlet is located at the extreme opposite end of the lake and buffered by a submerged dam so that short circuiting does not occur. The other storm drains entering the lake are small.

3. The lake is sufficiently deep so that wind induced turbulence does not greatly disturb bottom deposits and at most suspends near shore or bank material. Yet it is not too deep so that suspended material will not settle within the detention time.
4. The banks are well protected either by vegetation or gravel and the near shore area, by design, filled with sand and gravel.
5. The lake surface to depth ratio is substantial (8.7×10^4) promoting a high degree of reaeration which maintains, at least in the upper layers, aerobic conditions.

Some of the features of Lake Ellyn which make it an attractive community asset, features that should be incorporated into similar urban detention facilities if they are to be utilized by the public, include:

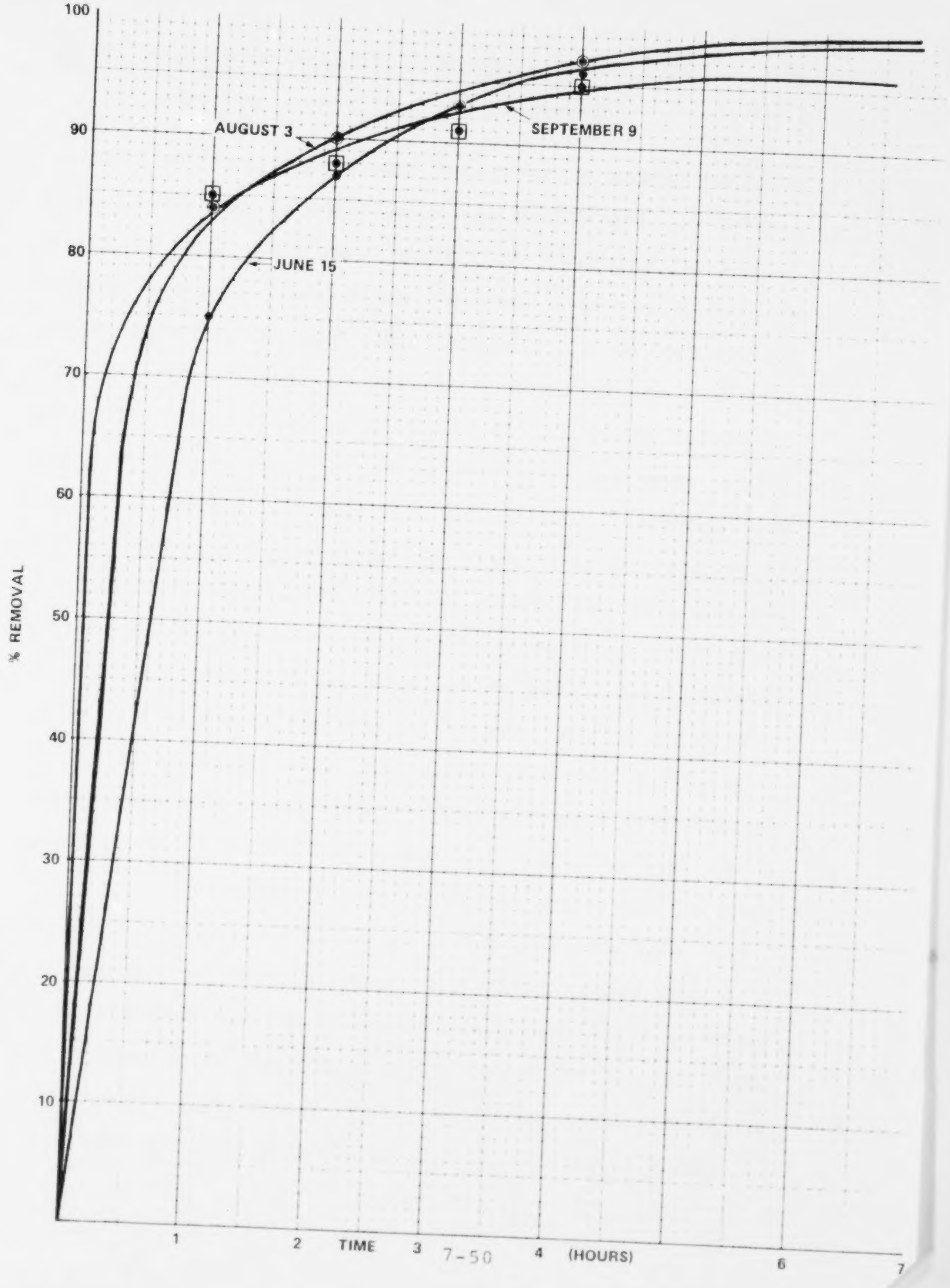
1. Beautifully landscaped park surrounding the lake.
2. Low banks permitting easy access to the water.
3. Little or no floating material or debris accumulation in the lake or along the shore.

4. Associated public facilities such as docks, clubhouses and boat launching ramps.

In designing a detention facility from the control standpoint, the inflow characteristics of the urban waste should be analyzed to ensure that there are no toxic substances reaching the lake which would create a public health hazard or nuisance. The next step would be to determine the settling velocities or settling time of the suspended materials in the runoff. In the case of Lake Ellyn, three settling tests were performed and the results are reported in Figure 7-2. In four hours, approximately 95 percent of the suspended material entering the lake according to these tests, would be settled -- this is less time than the discrete settling time for the incoming particle size distribution therefore flocculant sedimentation is occurring. The tests were performed in a laboratory with a six foot column and ports every one foot. At regular time intervals, samples were taken from each of the ports and analyzed for suspended solids. Stormwater entering Lake Ellyn was used for the tests.

The next consideration in terms of design would be detention time. Again using Lake Ellyn as an example and based on a hydrologic analysis done for the East Branch of the DuPage River during the 208 program (Hydrocomp, 1978 and Northeastern Illinois Planning Commission, 1980), there is only a 10 percent chance, in any year that the lake will

FIGURE 7-2: SETTLING TEST RESULTS



not provide four hours of detention (see Figure 7-3). Stated a little differently, there is a 90 percent chance that no event will yield a sufficient volume of water to totally displace the water previously detained in the lake. This assessment is based on the watershed being 16 percent impervious and the lake storage being one inch (44.8 acre-feet x 12 inches/534 acres), the Lake Ellyn conditions.

A similar analysis can be done for any watershed in the immediate vicinity knowing the drainage area and percent of imperviousness. Figure 7-4 relates these parameters to the detention time and storage requirements. The development of these relationships is dependent on the following assumptions:

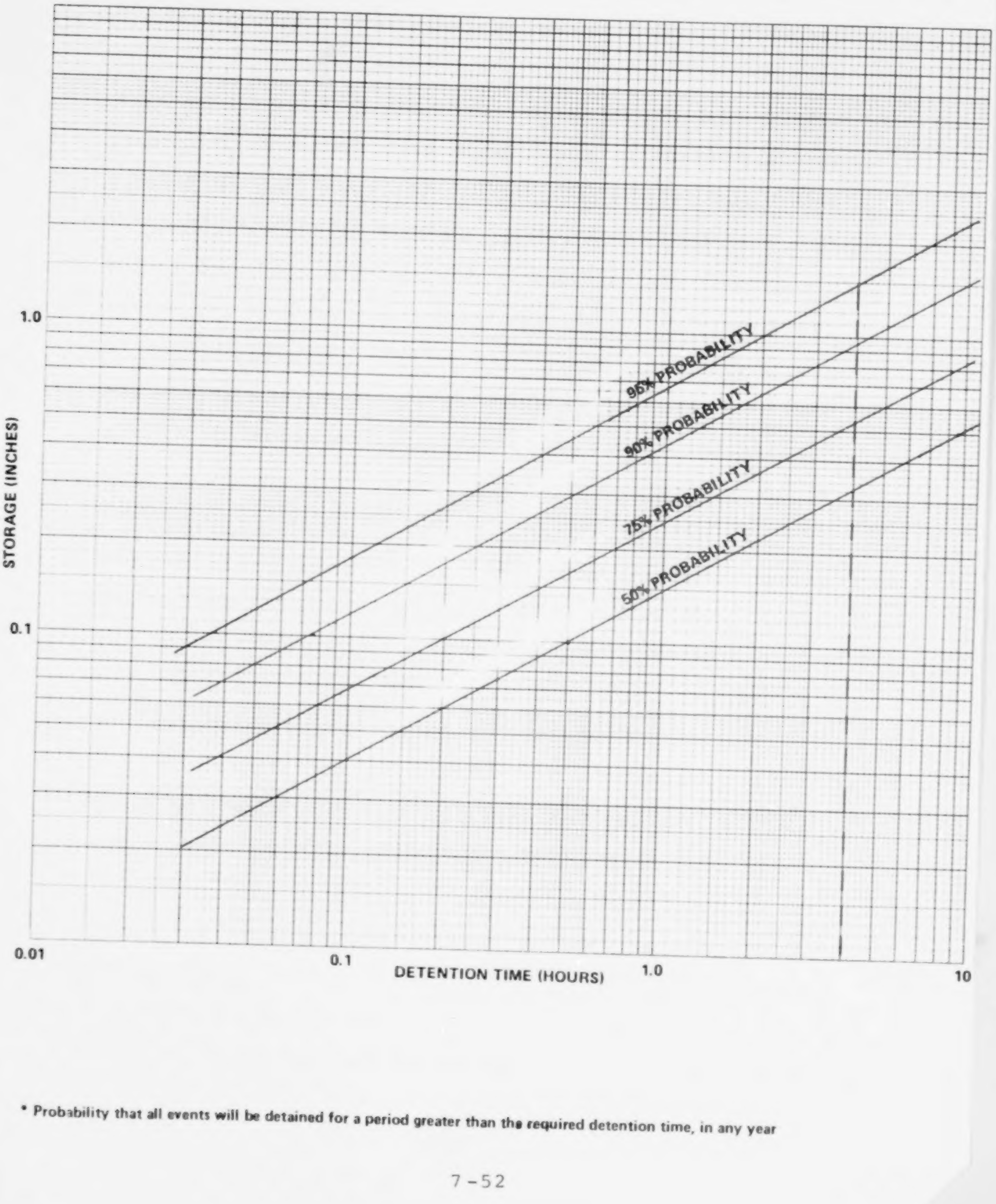
(1) The probability distribution of detention events (i.e., the time required to displace the detention volume) is described by the exponential probability function.

(2) The probability of occurrence in a given time period is defined by the binomial probability function.

(3) The storage facility is constructed to avoid short circuiting and withdrawals of water below the settling depth.

Given different levels of imperviousness and storage volume (measured in inches), the random variable, displacement time, was calculated. The resulting statistics are given in Table 7-27. The requirement of the exponential function

FIGURE 7-3: STORAGE VERSUS DETENTION TIME (16% IMPERVIOUS)



* Probability that all events will be detained for a period greater than the required detention time, in any year

FIGURE 7-4: REQUIRED STORAGE VERSUS DETENTION TIME

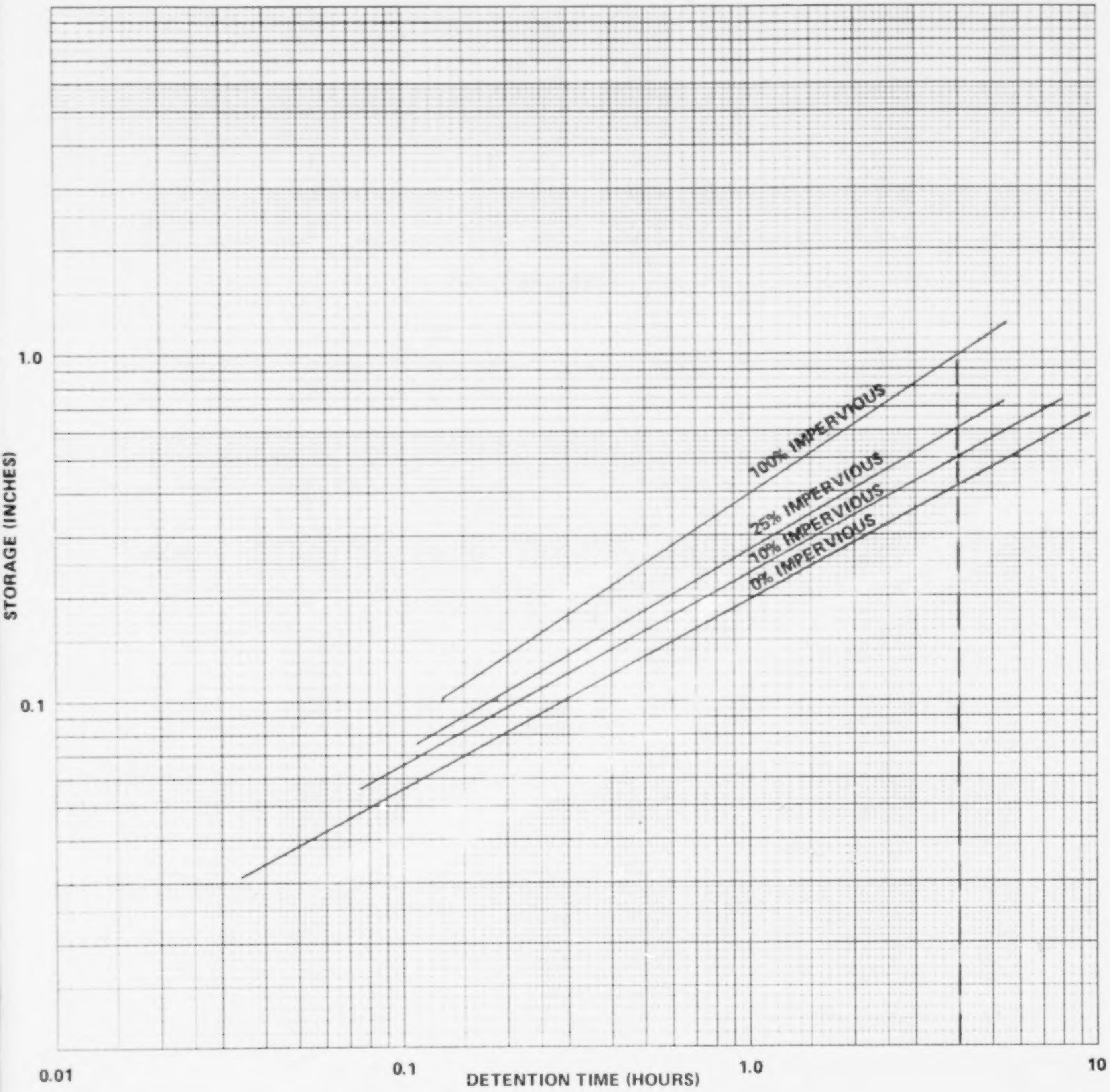


Table 7-27: Displacement Duration Statistics

Storage (inches)	Duration Mean (hours)	Standard Deviation	n	No. of Events Per Year
0 % Impervious				
0.1	80.95	111.09	1178	108
0.5	398.79	445.87	235	22.0
1.0	796.17	756.94	117	11.0
2.0	1600.57	1185.53	58	5.48
10% Impervious				
0.1	71.43	95.02	1329	123
0.5	352.75	345.78	265	24.8
1.0	705.35	617.04	132	12.4
2.0	1410.83	948.22	66	6.21
25% Impervious				
0.1	61.25	92.86	1557	143
0.5	302.40	295.67	311	29.0
1.0	602.69	476.42	155	14.5
2.0	1206.51	781.44	77	7.26
100% Impervious				
0.1	35.37	112.29	2694	248
0.5	173.75	255.38	538	50.4
1.0	347.49	354.08	269	25.2
2.0	695.10	494.27	134	12.6

is that the mean and standard deviation be equal. The parameter x is equal to the reciprocal of the standard deviation. This condition was not precisely met in each case but it was reasonably approximated. Further, for the hydrologic time series which was used, the frequency distribution of detention times appears exponential, i.e., grouped closely to the ordinate and rapidly dissipating with increasing detention time.

The application of these relationships to the design of a detention facility like Lake Ellyn with a 75 percent confidence that no event will exceed the storage capacity, or detention requirements in a year would be as follows: (1) The Lake Ellyn watershed is approximately 16 percent impervious, the settleable material entering the lake req9ires four hours detention time. (2) Moving vertically, on Figure 7-3, from four hours up to the 75 percent confidence line and then horizontally to the ordinate produces a value of 0.54 inches of storage. For the Lake Ellyn watershed this would mean approximately 24 acre-feet of storage, or 0.045 acre feet of storage per acre of watershed. This is approximately 54 percent of what is provided by Lake Ellyn. There is no doubt that Lake Ellyn, in terms of urban stormwater control, is "over designed" for the 25 percent level of risk. As previously noted, the lake provides sufficient storage to be 90 percent certain that no event will be determined for four hours or less.

Assuming a three foot depth for a detention facility and using the sample detention relationships given in Figure 7-4 which are for the 75 percent confidence level, approximately 1.3 percent of the surface area of a suburban watershed should be dedicated to detention storage if the technique is to be effective -- a greater or lesser percentage depending on the impervious area (see Table 7-28). The location, in northeastern Illinois of such detention facilities could well be along the receiving streams although upland from the 25 or 50 year flood levels for obvious reasons. Many counties in this region have purchased land along the rivers and detention storage would seem compatible with the current uses of this land.

The design recommendation certainly should have regional application and, given the available hydrologic data at the Northeastern Illinois Planning Commission, localized estimates can be computed for each drainage area, tailoring the results to the local hydrologic conditions.

Table 7-28: Area Required for Detention Treatment

Land Use	Percent Impervious	Storage Requirements[1] (inches)	Percent of Drainage Area Required for Detention Storage[2]
Parking Lot	100	1.0	2.8
Suburban and Commercial	25	0.6	1.7
Suburban	10	0.5	1.3
Undeveloped	0	0.4	1.1

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[1] Assuming a 75 percent certainty that all events in a year will be detained for a period greater than the four hours.

[2] Assuming the detention facility has an average depth of three feet.

CHAPTER 8: PUBLIC PARTICIPATION

Public involvement in this study focused on obtaining the active cooperation of public agencies and on a survey of the environmental habits and concerns of the citizens of the watershed. Information on this project and its objectives was presented in many forums. Activities in terms of information and participation are presented below.

Information Activities

Project staff presented descriptions of project activities and findings to the following groups during the course of the project.

DuPage County Mayors and Managers Conference - Environmental Concerns Committee

American Association of University Women - Glen Ellyn Chapter

IEPA Water Quality Technical Advisory Committee

NIPC Water Quality Technical Advisory Committee

Stormwater Detention and Flow Attenuation Seminar - Chicago, Illinois

Illinois Pollution Control Board

The two technical advisory committees are composed of professionals and lay people representing a variety of public and private interests. A listing of the groups represented on NIPC's advisory group follows:

Illinois State Water Survey

Hinsdale Sanitary District

U.S. Army Corps of Engineers
Chicago Department of Water and Sewers
Thorn Creek Drainage Basin Sanitary District
Illinois State Water Survey
Lake County Public Works

Lake County Public Works Department
Baxter & Woodman, Inc.

Northwestern Indiana Regional Planning Commission

Illinois Department of Transportation
Metropolitan Sanitary District of Greater Chicago
City of Lockport

DuPage County Health Department
U.S. Geological Survey
Sanitary District of Elgin
City of Elmhurst

U.S. Environmental Protection Agency
City of Naperville

Greeley & Hansen
League of Women Voters

The stormwater attenuation seminar was attended by consulting engineers and public works engineers representing 20 different firms and communities within the region. The Illinois Pollution Control Board is the legislative arm of the State of Illinois' water quality management and enforcement programs.

Participation Activities

A survey of environmental practices was sent to 1,931 households in the study area, 689 replies were received. In response to a request for comments on how to improve the quality of stormwater runoff into Lake Ellyn, the largest number of replies cited the overuse of road salt. The next largest category complained about sewer and street flooding. Other comments were made about animal control, litter and leaf control, sump discharges and the algal blooms in Lake Ellyn. Five people felt that there was a need for public information so that the harmful impacts on the water quality of Lake Ellyn could be kept to a minimum.

The actual involvement of public agencies in project work tasks was also utilized to ensure that the project had high visibility throughout the region. The following list presents the state and local agencies participating in the project.

Glen Ellyn Park District
Glen Ellyn Public Works Department
Glenbard School District No. 187
DuPage County Regional Planning Commission
Illinois Department of Energy and Natural Resources
Illinois State Water Survey
Illinois Department of Conservation

CHAPTER 9: INSTRUMENTATION

Sixteen different data collection programs were undertaken during this project. The instruments used to collect this data varied from grab samples using nothing more than collection vessels to automatic water quality samplers. A discussion of each major sampling program follows.

Atmospheric Deposition

The Illinois State Water Survey Atmospheric Sciences section was responsible for the analysis and reporting of this information. Locations of the two sampling sites were shown in Figure 1-3. Site one is a Commonwealth Edison Company power substation. At this site, the following was installed.

-Aerochem Metrics wet/dry collector, with an event pen to record lid movements.

-Bulk Collector, consisting of a support stand and 5 gallon plastic pail.

Site 2 was on the roof of the Glenbard West High School about 60 feet in the air with no interferences. A bulk deposition collector was operated at this site.

Precipitation

The Illinois State Water Survey operated one 15-minute rain gage at the Commonwealth Edison site previously mentioned. The rain gage was a Belfort weighing-bucket recording type. It was fitted with an Alter snow shield.

The U.S. Geological Survey operated a five-minute rain gage at each of their inlet and outlet runoff monitoring stations shown in Figure 1-3. These rain gages were of the volumetric type with a maximum resolution of 0.02 inches. Rain gages were connected to 16-channel tape analog-digital recorders.

Runoff Quantity

The U.S. Geological Survey was responsible for collection of runoff quantity data. Inlet and outlet stage measurements were made utilizing Stacom manometers. Measurements were recorded using 16-channel tape analog-digital recorders. Theoretical stage-discharge ratings were developed and verified by actual measurement using current meters. Stage-discharge plots were also recorded using a pen and strip chart recorder.

Runoff Quality

The U.S. Geological Survey was responsible for collection of runoff quality data. Inlet and outlet runoff quality samples were collected by Manning S-4051 automatic water quality samplers. Samplers were modified to draw three liter samples instead of the standard one liter sample. Discreet samples were collected at 7.5 minute intervals. Samplers were mounted on top of 18.1 cubic foot chest freezers fitted with modified covers. Samples were deposited into plastic milk containers located within the freezer. This insured that biological activity would be inhibited in the period before collection. U.S. Geological Survey personnel usually arrived on site within eight hours of a storm, thus collecting samples before they had a chance to freeze. Field specific conductance measurements were taken using Beckman and Electronic Switchgear conductivity meters. Field pH measurements were made using an Ocean Data Equipment Aqualab recorder.

Groundwater

The U.S. Geological Survey operated the groundwater monitoring program. Groundwater samples were collected by using a peristaltic pump at two, thirty-foot well sites and by means of lysimeters at depths of ten feet, thirteen feet and sixteen feet at two different sites.

Water Column

The Illinois State Water Survey, Water Quality Section was responsible for gathering water column quality data in Lake Ellyn.

In situ dissolved oxygen and temperature measurements were made with a galvanic cell oxygen analyzer equipped with a thermister. An oxygen meter, Yellow Spring Instrument Company Model 54, was standardized in lake surface water in which dissolved oxygen content was determined by the modified Winkler method as outlined by the American Public Health Association (1976). Alkalinity and pH determinations were made in the field using a Metrohm Herisau pH meter.

Lake Sediment

The Illinois State Water Survey, Water Quality Section was responsible for the collection of sediment quality data at Lake Ellyn. For physical and chemical characterization of sediment, three grabs with an Ekman dredge (6 x 6 inches) were taken at each station.

For benthic macroinvertebrate enumeration and identification, three grabs with an Ekman dredge were again taken at each station. These samples were then washed in a 30-mesh screen bucket with the residue placed in quart jars and preserved in 95 percent ethyl alcohol. In the laboratory, the samples were again washed in a 30-mesh sieve. The organisms were picked from the bottom detritus, identified and counted, and preserved in 70 percent ethyl alcohol.

In-situ measurement of sediment oxygen demand rates consists essentially of confining a known volume of water over a given bottom area. For this investigation, a small box type sampler, size 12 x 7 x 6 inches, made of 3/16 inch welded steel plate was used. The dissolved oxygen (DO) drop within the confined waters was monitored with a galvanic cell oxygen probe equipped with a stirrer. The stirrer-probe combination was implanted internally in the sampler, the details of which are given by Butts and Evans (1979).

As a first step, the DO probe was calibrated at ambient water conditions by the modified Winkler method (APHA, 1976). The stirrer-DO probe was installed in the sampler and a battery operated recorder was hooked into the meter to provide a continuous record of the DO usage. The sampler was then lowered from a boat to the bottom after all trapped air was carefully expelled. Temperature readings were taken at the beginning and end of a run. DO usage was also recorded manually at 5-minute intervals. Algal respiration was determined by the before and after DO levels in duplicate dark bottles incubated at mid-depth during each SOD run.

A private contractor collected information on the sediment depths at Lake Ellyn as well as supplementary quality data. Lake bottom contours were mapped during the fall of 1980. The perimeter was surveyed and permanent stations were located along the shoreline approximately 50 feet apart. A tag-line cable was pulled taut from a designation station to a corresponding station across the lake and used for measurement and sample location. A row boat was pulled along the cable to each measurement and sample site. This procedure established a grid of sample locations approximately 20 feet by 50 feet. Water depth measurements were made using a calibrated rod with a 9-inch plate affixed perpendicularly to its base. This instrument was designed not to penetrate the soft recent sediment that has accumulated in recent years. Results obtained from the measurements were used to construct a bathymetric map of the lake.

Thickness of accumulated sediment was measured with a fiber-glass stadia rod calibrated in tenths of feet. The rod was lowered through the recent sediment until it rested on the compacted clay layer which forms the original lake bottom.

The thickness of accumulated sediment was determined for each of 380 locations on the lake grid.

Sediment samples were collected at regular intervals along the cable using a US BMH-53 core sampler with a maximum core length of 12-inches. Extensions were attached to the handle to facilitate access in deeper water. Samples were stored in covered one-liter polyethylene containers labeled with a number and letter designating the sample location.

Road Dirt

The remaining data collection efforts were the responsibility of the Northeastern Illinois Planning Commission. The principal instrument for the collection of road dirt samples was a TORNADO model 3000 PRO portable industrial vacuum cleaner. The specifications on this unit were as follows:

Tank Material	ABS Plastic
Weight (lbs.)	16.5
Input H.P.	1.1
Wet Capacity (gals.)	1.1
Dry Capacity (gals.)	2.3
Waterlift (static)	80"
Orifice size	1 1/2"
Waterlift/C.F.M.	5.3"/69

The unit was powered by a gasoline generator during sample collection.

Vacuum efficiency with and without attachments indicated that an aluminum tube with flexible connector be used instead of flexible hoses to reduce friction losses. No nozzle attachment was used and samples were filtered through paper bags.

Sampling technique consisted of vacuuming a strip equal in width to the intake nozzle diameter (1 1/2") from curb to curb. After the required number of subsamples were collected in a particular traffic classification, the collection bag was removed from the vacuum tank, stored, and a new clean bag inserted. Sample bags were delivered to the DuPage County Health Department for analysis at the conclusion of sampling at the end of the day.

Roof Runoff

Sampling of roof runoff was accomplished by means of a plastic tube fitted to the end of the downspout and connected to a polythylene collection bottle. Roof runoff in excess of bottle capacity was allowed to discharge through a "t" fitting in the plastic tube.

Snow

Samples were collected from the entire snow column. Efforts were made to prevent the sample from containing soil or grass. Samples were collected in quart "Ball" jars.

Snow was scooped into the jars and packed using a plastic plunger. Jars were then sealed using the normal "Ball" covers.

Soils

Soils samples were collected using a one-inch O.D. stainless steel core sampler. Samples were collected in quart "Ball" jars. Jars were then sealed using the normal "Ball" covers.

Vegetation, Pavement, Road Salts, Catch Basins, Street Sweeper Hopper

Samples of material from these sources and sinks were of the "grab" type. Samples were stored in "Ball" jars sealed with routine "Ball" caps.

CHAPTER 10: QUALITY ASSURANCE

Five independent laboratories participated in the analysis of samples collected from the monitoring programs described in preceding chapters. A listing of these laboratories and the data for which they performed analyses was shown in Tables 1-1 through 1-3.

Laboratory Procedures

The analytical procedures followed by each of the laboratories is presented below.

U.S. Geological Survey

Procedures followed by the U.S. Geological Survey in their analysis of samples are specified in "Techniques of Water-Resources Investigations of the United States Geological Survey, book 5," "Selected Methods of the U.S. Geological Survey for Analysis of Wastewaters" and the U.S. Environmental Protection Agency's "Methods for Chemical Analysis of Water and Wastes."

Illinois State Water Survey, Atmospheric Chemistry Section

The Atmospheric Chemistry Laboratory of the Illinois State Water Survey is the Central Analytical Laboratory for the National Atmospheric Deposition Program. The analytical procedures used at the laboratory have been documented elsewhere (Peden, 1979).

Illinois State Water Survey, Water Quality Section

Sediment samples were examined for physical properties within one week after the samples were received in the laboratory. After the samples were allowed to settle quiescently for at least 48 hours, the supernate in the sample bottles was decanted off. The samples were then thoroughly mixed and used for all further analyses.

Consistency or the percent moisture content of the sedidment sample was determined by accurately weighing a portion of the mixed sediment, drying on a steam bath and then at 103°C for one hour, cooling, and reweighing. The loss of weight of the sample from the oven-dried sample, expressed as a percent of the original dry weight, was taken as the volatile fraction.

The sieve-pipet method (Guy, 1969) was used for particle size analysis. The fundamental principle of the pipet method is to determine the concentration of a suspension at a pre-determined depth as a function of settling time. Particles having a settling velocity greater than that of the size at which separation is desired will settle below the point of withdrawal after a certain time has elapsed. The time and depth of withdrawal are predetermined on the basis of Stokes' Law. The recommended times and depth of withdrawal for sampling particle sizes from 63u down to 2u based upon a range of water temperatures have been reported (Guy, 1969).

A well-mixed sediment sample was accurately weighed out and dispersed in a one-liter graduate and made up to one-liter with double deionized water. The dispersion was thoroughly agitated with a specially designed plastic plunger with at least 30 quick, deep plunges before the suspension was allowed to settle under quiescent conditions. After appropriate settling times, samples were withdrawn from 15 cm and 5 cm depths (representative of particle sizes [63u and 4u, respectively) for particle size analysis, analysis of heavy metals, and some nutrient analyses. Weights of sediments smaller than 63u and 4u were determined, after evaporation, through a steam bath, ovendrying overnight at 103°C, and desiccation. This weight, the initial sample weight, the consistency, and the volume of dispersion taken were used to calculate the particle size distribution.

Determinations for cadmium, copper, iron, lead, and zinc were made with atomic absorption spectroscopy after various aliquot sizes of the different size suspensions were digested with nitric acid and hydrochloric acid and made up to a desired volume (APHA, 1976). Determinations for arsenic and chromium were made by ICP (inductively coupled plasma) procedures on these digested suspensions.

Mercury determinations were made following the procedures of U.S. Environmental Protection Agency's 1979 Methods for Chemical Analysis of Water and Wastes, in which specially digested suspension samples are analyzed by cold vapor atomic absorption spectroscopy.

Determinations for pH as well as grease and oil were always made on the well-mixed sediment samples, whereas total phosphorous analyses were made on sediment suspensions (APHA, 1976). The table below lists these procedures.

Ammonia-N	Distillation followed by acidimetric titration
Total Kjeldahl-N	Digestion, and distillation followed by acidimetric titration
Nitrate-N (Extractable)	Chromotropic acid method
Grease and oil	Extraction method for sludge samples
Total phosphate-P	Sulfuric acid - nitric acid digestion followed by ascorbic acid method

Laboratory chemical analyses of water column quality were made according to *Standard Methods for the Examination of Waterj and Wastewater* (American Public Health Association, 1976). The procedures used are indicated below:

Chloride	Argentometric method
Chemical oxygen demand	Dichromatic reflux method
Ortho phosphate-P	Ascorbic acid method
Total phosphate-P	Digestion with sulfuric acid, nitric acid mixtures and determination by ascorbic method
Ammonia-N	Distillation followed by endophenol-hypochlorite colorimetric determination
Nitrate and nitrate-N	Chromotropic and diazonation methods
Kjeldahl-N	Digestion and distillation followed by endophenol-hypochlorite colorimetric determination

For determining the dissolved fractions of various chemical constituents, water samples were filtered through 0.45U filters. Filterable solids were determined by filtering water samples through glass fiber filters (Whatman GFC grade) using gooch crucibles.

For heavy metal analyses, the following sample preparation method was used. A representative portion of the water sample was digested several times in a beaker with a concentrated nitric acid and hydrochloric acid mixture on a hot plate, making certain that the sample did not boil. Finally, a small volume of concentrated nitric acid was added to the beaker and warmed to dissolve the residue. The sample was brought up to the desired volume with double deionized water and centrifuged to remove insoluble silicate and other materials.

Concentrations of cadmium, chromium, copper, iron, lead, mercury, and zinc were determined by using atomic absorption spectroscopy and by the ICP (inductively coupled plasma) procedure.

Water samples in a volume of 380 ml were collected for phytoplankton identification and enumeration. These samples were preserved in 20 ml of formalin at the time of collection and stored at room temperature until examined.

For algal identification and enumeration, the sample was thoroughly mixed for a one-ml aliquot pipetted into a Sedgwick-Rafter cell. A diferential interference contrast microscope equipped with a 10X or 20X eyepiece, 20X or 100X objective, and a Whipple disc was used for identification and counting purposes. Five short strips were counted. The phytoplankton were identified as to species and were classified into five main groups: blue-green, greens, diatoms, flagellates, and others. For enumeration, blue-green algae was counted by the trichomes. Green algae were counted by individual cells except _Actinastrum_, _Coelastrum_, and _Pediastrum_, which were recorded by each colony observed. _Scenedesmus_ was counted by each cell packet. Diatoms were counted as one organism regardless of their grouping connections. For flagellates, a colony of _Dinobryon_ or a single cel of _Ceratium_ was recorded as a unit.

For zooplankton identification and enumeration, 20 liters of depth integrated water samples were filtered through a Wisconsin plankton net, and the material retained in the net was washed into a plastic container with deionized water and preserved in 95 percent ethanol.

In the laboratory, the volume of the sample was made up to equal 200 ml, and one-ml aliquot was pipetted into a Sedgwick-Rafter cell. A differential interference contrast microscope was used to identify and enumerate the zooplanktons. Five strirps were counted and the results extrapolated.

DuPage County Health Department

The DuPage County Health Department performed all water column analyses in conformance with the procedures outlined in 40CFR136, "USEPA Guidelines Establishing Test Procedures for the Analysis of Pollutants - Amendments," December 7, 1976 and all solids analyses in accordance with the U.S. Geological Survey "Techniques of Water Resources Investigations, Book 5, Chapter A1, Water and Fluvial Sediments."

The U.S. Environmental Protection Agency was informed of any deviations from these references.

AquaLab

Laboratory methodology was based on one or more of the following references.

Methods for Chemical Analysis of Water and Wastes, U.S. Environmental Protection Agency, 1979.

Standard Methods for Examination of Water and Wastewater, American Public Health Association, 14th Edition, 1975.

Annual Book of Standards, Part 31, American Society for Testing Materials.

Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Efluents, U.S. Environmental Protection Agency, 1975.

Methods of Soil Analysis, American Society of Agronomy, 1965.

Official Methods of Analysis of the Association of Official Analaytical Chemists, 12th Edition, 1975.

Analytical Chemists, 12th Edition, 1975.

Quality Assurance Programs

The quality assurance programs followed by the various laboratories are outlined below.

U.S. Geological Survey

U.S. Geological Survey quality assurance procedures and results for this project are available from their Atlanta, Georgia laboratory.

Illinois State Water Survey, Atmospheric Chemistry Section

As previously stated, the ISWS Atmospheric Chemistry

Laboratory is the Central Analytical Laboratory for the National Atmospheric Deposition Program. copies of quality assurance procedudres and results may be found in quality assurance reports for the period of this project.

Internal quality assurance activities include:

1. Preparation of daily banks of filters used to remove insoluble materials from precipitation samples;
2. Continuous monitoring of analytical detection limits;
3. Splitting every 20th sample, with analaysis as blind duplicates;
4. Comparison of measured conductivity and pH against values calculated from measured concentrations of major ionic constituents;
5. Comparison of measured positive and negative ion totals, with reanalysis of any samples out of balance by an unusual amount;
6. Periodic reanalysis of stored samples analyzed earlier;
7. Monthly reanalysis of National Bureau of Standards and U.S. Environmental Protection Agency reference samples.

External quality assuranace for the NC-141 program is directed by a U.S. Geological Survey Laboratory, and includes:

1. Analysis of U.S. Geological Survey reference samples;

2. Blind analyses of artificial precipitation samples submitted through regular sampling sites; and
3. Periodic evaluation of laboratory procedures and instrumental methods.

A regular program of quality assurance is also carried out at the Crocker Nuclear Laboratory, University of California-David. This program includes:

1. Extensive interlaboratory comparisons;
2. Regular evaluation of gravimetric standards; and
3. Random re-analysis of previously-analyzed samples.

llinois State Water Survey, Water Quality Section

Quality assurance activities and results for this project for both sediment and water column analyses are available from the Illinois State Water Survey, Water Quality Section.

DuPage County Health Department

The DuPage County Health Department's laboratory meets or exceeds the requirements set forth by the Illinois Department of Public Health and Illinois Environmental Protection Agency in their adopted rules for the certification and operation of environmental laboratories.

The DuPage County Health Department laboratory completed the following quality assurance activities.

1. Participated in an inspection of laboratory equipment and procedures by U.S. Geological Survey.
2. Participated in an audit sampling program using performance check samples prepared by U.S. Environmental Protection Agency.
3. Ran control samples of known value in parallel with each constituent determination to evaluate procedural accuracy.

AquaLab

Elimination of Determinate Errors

Reagent Blanks: The first step in the elimination of determinate errors is to determine the background or blank of each of the reagents and solvents used in a given method of analysis. The conditions for determining the blank must be identical to those used throughout the analysis. If background or interfering substances are found, the reagent or solvent must be replaced.

Method Blank: This second step in the elimination of determinate errors is conducted by following a procedure step by step to determine the cumulative blank of reagents and solvents. If there is a method blank, it should be eliminated or reduced so that consideration may be taken when calculating the concentration of specific constituents in the samples being analyzed.

Method blanks are determined each time an analysis is made.

Bacteriological Control: Bacterological analyses are checked for determinate blanks by the use of the following:

Negative Control: Sterile water is run as a sample in each group and must exhibit no growth. This acts as a check on the entire procedure for sterility, sterile technique, etc.

Positive Control: A loopful of specified bacterial stock culture in 200 ml. of Sterile Water is run as a sample in each group and must show growth. This growth confirms the viability of the culture media and the non-existence of toxic substances in the filters, absorbent pads, etc.

Check of Standard Curve

As specified in the appropriate method reference, Standard Curves have been developed for absorbance vs. concentration in all spectrophotometric methods. This Standard Curve is the basis for determination of the concentration of a substance in a sample from the absorbance value. These curves are determined from the procedural analysis of a series of standards. Replicate standards are routinely analyzed in a sample run to compare with the standard curve. Any replicate standard which does not produce an absorbance within the specified deviation points out that a problem exists in one of the following areas: standard solution preparation, procedure, reagent quality, interfering substances, or instrument failure. A remedial study is immediately undertaken and continued until the source of the problem is found and eliminated.

Quality Control Sample Analysis

The analysis of Q.C. samples is the primary method used in the laboratory for monitoring analytical performance. This monitoring is accomplished with the analysis of replicate or "split" samples and "spiked" samples and are alway included in a specific sample run. AQUALAB's policy for Q.C. sample analysis is as follows:

> Approximately every 10th sample submitted to the laboratory is split into duplicate samples with the same designated Analysis Number. The second portion of the sample is additionally designated "QC". The analysis of this Q.C. sample will document that reproducible results are being obtained if the resulting data agree favorably within the known precision of the method. This precision is evaluated as is shown in evaluation performance.

Approximately every 20th sample submitted to the laboratory is split into triplicate samples with the same designated Analysis Number. The second portion is additionally designated Q.C. (as shown above) and the third is designated "SPIKE". The analysis of this spiked sample will document that the procedure utilized is actually recovering what is in the sample if the resulting data fall within the known accuracy of the method. This accuracy is evaluated as shown in evaluation of analytical performance.

The most beneficial way of reviewing analytical performance is through the preparation of quality control charts. Plotting of said data systematically answers the questions as to whether or not the laboratory analyses are under control. It is also useful in observing developing trends of positive or negative bias. The charts are prepared using the following Q.C. sample procedures:

Precision: Data developed as shown above is applied to a chart. This specifies the upper and lower control limits for test results as compared to the standard deviation allowed for that parameter. Evaluation of this Quality Control Chart allows the Technical Director to see any deviation from acceptable limits.

Accuracy: Data developed as shown above is applied to a chart which specifies the lower control limit for recovery of a known quantity of a constituent to insure that what is reported is a highly reliable percentage of what is known.

Anion-Cation Balance: As an additional evaluation tool, an Anion-Cation Balance can be performed per Standards Methods, Section 100C, on samples where the data required provides sufficient base for the calculation. Percent deviation from balance is the basis for the analytical evaluation as follows:

$$\% \text{ error} = \frac{100\ (\text{Cations} - \text{Anions})}{\text{Cations} + \text{Anions}}$$

A broader form of evaluation of laboratory performance is through the participation in interlaboratory round-robin studies. This allows the analyst to compare his individual performance against other laboratory persosnnel and also checks the reliability of methods for particular analyses. These samples are analyzed as part of the routine sample load and should be regarded as "blind samples".

CHAPTER 11: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Stormwater Constituents

If the influent to Lake Ellyn is characteristic of urban stormwater runoff and violations of state water quality criteria define a problem, only total phosphorus, total lead and total copper concentrations are cause for concern. On average, phosphorus exceeds the State of Illinois' water quality criteria by 860 percent, copper by 105 percent and lead by 124 percent. These and all of the other constituent, event mean concentrations were found to be well below lethal thresholds. When considering the bioavailability of the contaminants, as would be represented by their dissolved fractions, urban stormwater poses no detectable threat to aquatic life. Further, if urban stormwater were characterized by the effluent from Lake Ellyn, the margin of safety would be substantially increased. Whether dissolved or total, none of the observed effluent constituent concentrations, except for phosphorus, exceed the state's criteria and they are substantially below toxic thresholds. Both influent and effluent event mean, constituent concentrations were found to be lognormally distributed. This conclusion is very significant in terms of assessing the frequency and duration of constituent concentrations in urban stormwater.

Constituent Sources

Tables 6-9 through 6-12 summarize constituent loads to the Lake Ellyn watershed and its transport system. Table 11-1 summarizes

Table 11-1: Principal Constituent Sources

	Lake Ellyn Watershed			Lake Ellyn Transport System		
Constituent	Principal Sources	Percent	Unit Load (lbs/acre/yr)	Principal Sources	Percent	Unit Load (lbs/acre/yr)
Total Solids	Vegetation	55	3600.0	Soils	31	1070.0
	Soils	16	1070.0	Street Salting	24	816.0
	Street Salting	12	820.0	Pavement Decomposition	20	676.0
	Pavement	10	57.0			
Chloride	Street Salting	93	490.0	Street Salting	> 99	490.0
Phosphorus	Vegetation	54	9.9	Vegetation	43	6.9
	Fertilizer Application	27	4.9	Animals	23	3.3
	Animals	14	2.4	Fertilizer Application	17	2.8
Copper	Traffic	50	0.20	Traffic	61	0.08
	Vegetation	16	0.06	Soils	12	0.02
	Atmosphere	14	0.06			
Lead	Traffic	84	1.87	Traffic	88	1.00
Zinc	Construction Material Decomposition	34	0.52	Construction Material Decomposition	29	0.17
	Atmosphere	25	0.47	Traffic	28	0.16
	Traffic	21	0.32	Atmosphere	23	0.14

these data, highlighting the principal sources and their relative contribution.

Atmospheric deposition, both precipitation and dryfall, contributes 25 percent of the total zinc entering the watershed and 23 percent of the zinc reaching the transport system. Atmospheric deposition also contributes 14 percent of the total copper to the watershed.

Fifty percent of the total copper, 84 percent of the total lead, and 41 percent of the total zinc are contributed to the watershed by traffic. Most of the copper probably comes from brake lining wear, most the lead from gasoline combustion exhaust, and most of the zinc from tire wear. Traffic also contributes 61 percent of the copper, 88 percent of the lead and 28 percent of the zinc reaching the transport system.

The decomposition of streets, parking lots, driveways and curbs is a significant source of total solids, contributing 10 percent of the load to the watershed and 20 percent of the load entering the transport system. While heavy metals are present in paving material they were not found in significant quantities.

The direct application of fertilizers and deicing chemicals are largely responsible for the phosphorus and chloride loads, respectively. Fertilizer applications contribute 27 percent of the total phosphorus to the watershed and 17 percent of the load to the transport system. Street salting is responsible for 12 percent of the total solids reaching the watershed and virtually all of the chloride. Twenty-four percent of the total solids reaching the transport system come from street salting.

Domestic and wild animals are responsible for 14 percent of total watershed phosphorus and 23 percent of the phosphorus reaching the transport system. Most of this load is from wild animals (birds, squirrels and rabbits). Migratory birds contribute most of the phosphorus load from animals to Lake Ellyn.

Vegetation is the principal source of solids in the watershed. It is also the principal source of total phosphorus and a significant source of copper. The influence of vegetation on the loads reaching the transport system is somewhat less. It is responsible for 18 percent of total solids and 43 percent of total phosphorus.

Soils, either through erosion by surface runoff or shallow groundwater and baseflow, contribute 16 percent of the total solids to the watershed. They are the number one source, however, of solids moving to the transport system. The decomposition of building materials (i.e. gutters, paint, shingles) can and do contribute constituents to the watershed. In fact, it is the principal source of zinc to the watershed and to the transport system.

Roofs

Total solids, phosphorus and metals are entrained in runoff from roofs (Table 6-8). Concentrations are about an order of magnitude higher (TS 97.7 ppm, TP 0.41 ppm, Cu 0.06 ppm, Pb 0.10 ppm, Zn 0.33 ppm) than found in precipitation. The zinc concentration in roof runoff is twice as high (0.330 ppm) as that found in stormwater runoff to Lake Ellyn (0.171 ppm). Other constituent concentrations are similar between roof runoff and stormwater to the lake. Roof runoff transports 39 percent of total watershed zinc. It is interesting to note that concentrations of total phosphorus, total copper, and total lead in roof runoff are at or exceed the State's water quality criteria. Concentrations of the other constituents do not exceed these criteria.

Pervious Surfaces

Pervious surfaces receive significant inputs of metals from traffic (Table 6-7). Metals concentrations found in snow on parkways near curbs are 20 to 400 times higher than concentrations in snow away from traffic influences. Chloride concentrations are 150 to 500 times higher and total solids concentrations 30 to 80 times higher. Total phosphorus concentrations are 20 to 60 times higher. A marked increase in constituent concentrations in curbside snow was noted with increasing traffic volume, indicating the importance of traffic in constituent deposition. The principal sources of solids to pervious areas are vegetation (1,790,000 lbs/year) and displaced road dirt (269,000 lbs/year). Roof runoff contributes most of the total zinc to pervious areas (207 lbs/year). The removal of grass clippings and leaves through regular litter pickup is an important activity since nearly three-quarters of all solids reaching pervious areas are controlled by this means. Over 90 percent of the phosphorus load to pervious areas is controlled by grass and leaf collections.

Streets and Parking Areas

Most of the solids reaching streets and parking areas come from pervious runoff (41 percent or 510,000 lbs/year) and street salting (22 percent or 278,000 lbs/year) (Table 6-6). Street salting is the only significant source of chloride (168,000 lbs/year). The principal source of phosphorus is pervious runoff (270 lbs/year). Traffic is the principal source of metals.

Stormwater runoff impacts both the quantity and the particle size distribution of road dirt. Typically, runoff from the Lake Ellyn watershed has enough energy to move particles less than 500u but not enough to move particles above that size. Both the load and relative percentage of material greater than 500u on streets were more likely to increase than decrease as a result of runoff. Road dirt loads increase in the absence of rainfall or street sweeping. Particles less than 63u were found to increase more rapidly than other sizes in the absence of rainfall or sweeping.

Street Sweeping

Street sweeping is relatively ineffective for the collection of particles less than 500u. Since 99 percent of the particles entering Lake Ellyn are smaller than 500u, street sweeping is not an effective control measure for this watershed. Street sweeping is also subject to climatic limitations imposed by frequent rainfall in spring, summer, and fall and snow and ice in the winter.

Street sweeping removes from streets and parking areas 46 percent of the total solids, about 16 percent of the total phosphorus, 30 percent of the total copper, 52 percent of the total lead, and 46 percent of the total zinc (Table 6-6). However, street sweeping removes from these areas only 11 percent of the total solids less than 500u. Correspondingly, sweeping removes only 8 percent of the phosphorus, 15 percent of the copper, 26 percent of the lead and 23 percent of the zinc associated with particles less than 500u -- those most likely to be transported by runoff to Lake Ellyn. The impact of sweeping is further reduced by the fact that not all material less than 500u is washed away by a runoff event. This means that although sweeping removes particles which could be transported, it might have no effect on event pollutant concentrations since a sufficient reservoir of material less than 500u always remains.

Catch Basins

Based on their low trap efficiency for all constituents catch basins in the Lake Ellyn watershed are not a viable control strategy. Catch basins in the Lake Ellyn watershed capture about six percent of total solids reaching them (Table 6-4). They trap about 10 percent of influent suspended solids; however, catch basins remove only about two to five percent of the phosphorus and metals in street washoff. Based on the measured accumulations of materials in catch basins during the study, about 10 percent of their volume is filled annually.

Catch basin sludge was found to contain fewer metals and phosphorus than Lake Ellyn sediment. Catch basin sludge is very similar, in particle size distribution and constitutent concentrations, to road dirt. The constituent concentrations of lake sediment are similar to those of road dirt for the particle size fraction less than 63u (Table 6-1). Although 95 percent of the material washed from the streets to catch basins is less than 500u in size, only 35 percent of the material in catch basins is less than 500u. Therefore, it is apparent that smaller particles are moving off street surfaces, through catch basins and are settling in Lake Ellyn.

Catch basins may serve a useful purpose by trapping larger particles (> 500u). In these instances, catch basins may serve to keep storm sewers from clogging. However, the preferred control strategy would be to eliminate erosion to storm sewers.

Detention

Detention storage, as provided by Lake Ellyn, modifies constituent concentrations and, in most cases, removes and immobilizes constituent materials. Except for chloride and ammonia, the means and maxima of all reported constituents were substantially reduced (Tables 7-2 through 7-14). This reduction ranged from a factor of two to over one order of magnitude. For example, the maximum observed total organic carbon concentration entering Lake Ellyn was 28.0 mg/l while the maximum outflow concentration was 13.6 mg/l. In the case of total suspended solids, the change in concentration was from 1,030 mg/l to 42.1 mg/l. Chloride concentrations in the lake increased during the winter months and during the spring the effluent concentrations often exceeded the influent concentrations -- the maximum influent concentration was 86.0 mg/l while the maximum effluent concentration was 224 mg/l. Nitrates are being converted to elemental nitrogen and organic material is being converted to ammonia in the lake; as a result, effluent nitrate concentrations are lower than influent concentrations and the reverse is true for ammonia. The maximum influent concentration of ammonia was 0.83 mg/l while the maximum concentration of ammonia in the effluent was observed to be 1.24 mg/l.

On an annual basis, the trap efficiency of Lake Ellyn ranges from + 0.90 for nitrate and nitrite to -1.32 for dissolved lead (Table 7-26). The trap efficiency, in part, relates to the physical characteristics of the constituent, whether it is in the dissolved or solid state, and to chemical transformations within the lake. Those constituents adsorbed to suspended solids or in the solid state have higher trap efficiencies, generally, than those constituents in the dissolved state. Such dissolved constituents as chloride tend not to accumulate in the lake and are moved in and out on a seasonal basis. Nitrates and nitrites are deposited with solid materials and then converted to elemental nitrogen due to the anoxic conditions found at the bottom of the lake. This results in high trap efficiency relative to nitrates and nitrites. The decomposition of organic material adds ammonia leading to a low trap efficiency, -0.56 for this constituent. Some 87 percent of the total lead is trapped by the lake, however, part of this load is returned to the water column through chemical complexing with chloride. Consequently, the trap efficiency of Lake Ellyn relative to dissolved lead is a -1.32, (i.e., 132 percent more dissolved lead leaves Lake Ellyn than enters it). Other than for chloride, ammonia and dissolved lead, the constituent trap efficiencies were positive ranging from 0.14 for total organic carbon and 0.25 for BOD_5 through 0.6 for total phosphorus to 0.78 for zinc, 0.81 for copper, and 0.87 for total suspended solids.

Over 96 percent of the solids entering Lake Ellyn are delivered through baseflow (58 percent) or stormflow (38 percent) (Table 6-2). Ninety-nine percent of the solids in baseflow are dissolved. About 50 percent of the solids in stormwater are dissolved. Virtually all of the suspended solids entering the lake in baseflow and over 83 percent of the suspended solids in stormflow are less than 63u in diameter. Almost all of the solids in stormflow are less than 500u in diameter. Suspended solids leaving the lake either in baseflow or stormflow are virtually all less than 63u in diameter.

Stormwater is the most important source of phosphorus (52 percent), copper (85 percent), lead (95 percent), and zinc (62 percent). Baseflow contributes most of the chloride (95,400 pounds annually or 70 percent of total load) and 40 percent of the phosphorus load. Roof runoff is responsible for 28 percent (50.5 pounds annually) of the zinc loads.

Chloride levels in Lake Ellyn are highest in early spring (170 ppm) and lowest in late fall (39 ppm). High concentrations correspond to the time when salt is being applied to streets and washed into the lake. Phosphate, ammonia, and metals concentrations in the lake are highest in the summer. These high concentrations result from stormwater runoff, most of which occurs in late spring and summer.

The concentration and load reductions are, of course, gained by an increase in constituents in the sediments. Almost 87 percent of the sediment in Lake Ellyn is less than 63 microns in diameter. In regard to organic matter, nutrients and heavy metals, the sediments found in Lake Ellyn are well above ranges found in normal, non-urban lakes. Lead and phosphorus are extreme cases. The range of lead concentrations in a rural lake might be from 15 to 100 ppm while the concentration found in Lake Ellyn sediments is over 1,000 ppm. The higher content of organic material causes depressed oxygen concentrations at and near the solid/aqueous interface which not only affects aquatic life in this zone but also chemical transformations such as the reduction of nitrates and dissolution of lead and other heavy metals.

Although some priority pollutants were found in Lake Ellyn sediment (e.g. a phthalate ester and numerous polycyclic aromatic hydrocarbons), none were present in sufficient concentrations for concern. Lake Ellyn sediment does not qualify as a hazardous waste under USEPA's EP toxicity criteria.

There are four physical features of Lake Ellyn which make possible the high trap efficiencies and, thereby the modification of urban stormwater constituent concentrations. The first of these features is that the inlet is separated from the outlet by approximately 600 feet, at the opposite end of the lake. The second is the existence of a submerged dam, near the inlet, which dissipates and distributes the energy of incoming stormwater -- it all but eliminates the possibility of short circuiting. The third is the lake volume of detained water (45.0 acre feet) is sufficient to ensure that there is only a 10 percent chance in any one year that a runoff event will totally displace the resident water volume (see Chapter 7). Further, there is a 90 percent chance that all events will be detained for at least four hours, the requisite detention time for settling 95 percent of the suspended materials. Consequently, the effluent, under most hydrologic conditions, is simply displaced lake water and not the immediate runoff from the watershed. Fourth, the mean depth of the lake is five feet which is deep enough to ensure that the zone of consolidation is undisturbed by the movement of water through the lake; consequently, materials that settle are not subsequently entrained. The only materials that reenter the water column, at least in regard to the measurements taken during this study, were those constituents that were dissolved by one means or another after entering the lake.

Source Control

Source control is not a practical means for reducing urban stormwater constituents in the Lake Ellyn watershed. The sources of contaminants are very diverse, and in many instances, the principal source is an essential component of society (automobiles), a service demanded by the public (street salting) or a source already being controlled to the maximum extent practical (soil erosion). For example, none of the four principal sources of total solids (soils, street salting, pavement decomposition, and vegetation) are responsible alone for more than one-third of the total solids load. Glen Ellyn's streets are all in generally good condition and the watershed is well turfed making further control of solids from these sources impractical. Glen Ellyn also collects grass clippings and fallen leaves on a routine basis so improvement in controlling this source is also not practical. Discontinuing street salting would virtually eliminate chloride loads but this action would cause winter driving hazards.

Phosphorus loads result from vegetation, animals, and fertilizer applications. Control of wild animals is obviously impractical and no adequate substitute is available for fertilizer applications, given social attitudes about urban landscapes.

Most of the copper and lead come from traffic. Elimination of this source from the Lake Ellyn watershed is obviously infeasible. No single source of zinc contributes more than 30 percent of total zinc. Important sources are the decomposition of building materials, traffic, atmospheric deposition, and vegetation. Replacement of galvanized building materials is an expensive proposition and would only eliminate 29 percent of zinc loads. Reduction of atmospheric loads would require regional control strategies but would only eliminate 23 percent of zinc loads to the transport system.

Utilization

Urban stormwater is not so much a resource out of place as it is a resource that has not been properly developed and utilized. Clearly, the chemical characteristics of stormwater are important to its use, but how stormwater is stored on the land and conveyed through urban areas are of greater importance. Its use in the future could be greatly increased if more land were allocated for its storage and conveyance and if proper management is applied.

By no stretch of the imagination is urban stormwater a chemically attractive substance; and yet, it can be and should be utilized as illustrated by its use in Lake Ellyn. Stormwater is not pure but it does rid our urban watersheds of substantial waste materials moving them to locations, such as detention facilities, where these materials can be immobilized and more efficiently removed. Within the next 20 - 30, years portions of Lake Ellyn may have to be dredged as would any urban stormwater detention facility. But in the meantime, the lake, functioning as a control strategy, is being used for a number of other activities providing substantial benefits to the community (e.g. aesthetics, fishing, boating, skating). Any urban stormwater control facility designed to emulate the characteristics of Lake Ellyn will achieve not only an improvement in water quality but benefits in terms of recreation and aesthetics. Lake Ellyn represents a control strategy which need not be fenced but rather is open to public use.

With only minor modifications to Lake Ellyn and with only a little improvement in the design and maintenance of other larger detention facilities found in northeastern Illinois, urban wildlife habitats could be substantially expanded and improved. At present, for example, there are no emergent plants in Lake Ellyn, yet these plants would help control nutrients, dissipate the energy of flood and wind induced waves and provide food and shelter for fish and other aquatic life. In addition, nearshore areas of the lake, could be underlaid with suitable substrate in order to promote spawning of desired fish species. With appropriate environmental management programs (e.g. periodic dredging and maintenance of substrate and aquatic vegetation) such lakes could serve to improve urban aquatic resources.

To ensure high trap efficiency and corresponding reduction in constituent concentrations, inlets and outlets of detention facilities should be separated to the maximum extent possible. Detention facilities also need to be sufficiently deep to preclude entrainment of trapped materials from the zone of consolidation. Depths should also be sufficient to provide for maintenance of fish life, but not so deep that they promote anoxic conditions leading to nuisances (e.g. odors) and chemical transformations which adversely affect the quality of the effluent. Typically, critical depths to avoid anoxic conditions are a function of reaeration potential and vary from lake to lake. In general, depths over ten feet may present the possibility of stratification and anoxic conditions unless mechanical aeration is provided.

To promote the use of detention facilities, the design should accommodate public access and reflect community values. In this regard, bank slopes should be very gradual ensuring easy access to the water without the fear of slipping or falling. The banks should be protected from erosion by vegetative cover or by other suitable materials. Aquatic habitats, including the placement of appropriate substrate materials and plants, should be provided if the propagation of fish and species diversity is desired.

Finally, access for maintenance equipment should be incorporated in the design.

Recommendations

Source Control

At a minumum, a basic program of source control should be carried out by management agencies responsible for urban watersheds. Such programs, found to be important in the Lake Ellyn watershed, should encompass erosion control, collection of leaves and grass clippings, minimal application of road salt for ice control, and routine street surface maintenance. If a sound source control program is already in place in an urban watershed, further investments are not recommended since, based on study results, they will have little effect on receiving water pollutant loads.

Special efforts should be directed at toxic materials. Source control is the only effective means for keeping these substances out of receiving waters. Urban management agencies must question the benefits of using materials containing toxic substances versus the risk posed by their release to the environment. Where it is essential that toxic materials be used, application programs should be carefully designed to prevent the introduction of these substances to transport systems (e.g. observing recommended application rates and conditions, avoiding overspray to streets and sewers, considering climatic factors such as the likelihood of precipitation).

Street Sweeping

Street sweeping should not be employed beyond levels of "good housekeeping" since this is an ineffective means of removing pollutant materials in this climatic region. Street sweeping should continue to be used for general street litter control to yield aesthetic benefits.

Catch Basins

Catch basins should not be considered an effective means of controlling urban stormwater pollutants. Further investment in catch basins for stormwater pollution control is not recommended.

Detention Storage

Wet-bottom detention storage should be employed where water resources benefits can be obtained through reductions of urban stormwater pollutants.

Detention facilities should be designed to serve regional rather than on-site needs in order to maximize pollutant removal capabilities and secure additional benefits such as aesthetics and aquatic life, and recreation. The design of detention facilities should consider the conclusions presented in Chapter 7 with respect to volume, depth, and inlet/outlet relationships.

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APPENDIX

LAKE ELLYN WATERSHED ENVIRONMENTAL PRACTICES SURVEY

ANALYSIS
BLOCK 1-93

1931 Questionnaires sent

5.33 % Vacancies 35.68 % Responses 58.98 % No Responses

Of the respondents to the survey, 81.59 % lived in single family dwellings, 9.4 % lived in multi-family dwellings and 8.4 % were commercial or public buildings. .051 % did not respond to this question.

Respondents perceived the area around their homes or business as:
9.4 % Mostly bare ground or pavement
54 % Mostly covered with mown lawn
0.7 % Mostly covered with unmown lawn and brush
35 % Mostly covered with a significant amount of lawn and pavement
0.8 % Did not respond

They felt that their lots were
3 % Very poorly drained
7.9 % Poorly drained
62.6 % Fairly well drained
25.7 % Well drained
0.6 % Did not respond

They indicated that they thought that the amount of porous areas on their lot was:
12.7 % - 10% - 40%
55.4 % - 40% - 70%
21.8 % - More than 70%
2.2 % Did not respond
7.7 % 0 - 10%
When asked to describe where stormwater from their roof, driveway and sidewalk goes,
20.4 % Said that it flows indirectly to the storm sewer (down spouts flow to driveway)
9.2 % Said that it flows directly to the storm sewer (down spouts directly connected to storm sewer)
46.3 % Said that it flows on the to their yard and excess runs to storm sewer
.7 % Said that the stormwater is stored for use during dry weather
16.2 % Said that their land can absorb their stormwater and that from the road and other paved areas, except for major storms
6.8 % Did not respond

Response to whether the respondents applied fertilizers to their lawns or gardens was:
19.9 % Never
1.7 % Heavily, just before a rain, several times a year
26.8 % Several times a year, without any soil tests.
3.5 % only as indicated by soil tests and after a rain
11.2 % Rarely
0.1 % Did not respond

The brands most often used were ______________________________

(Also ______ respondents contracted with professional lawn care services to treat their lawns).

Responses to whether the respondents used pesticides or herbicides was
63 % Never or not applicable
3.4 % Frequently with all wash mixing containers put into the storm sewer
9.4 % Frequently with all wash water and containers buried or put into the garbage disposal
15.9 % Occasionally
7.8 % Did not respond

The brands most often used included Most brands

Other comments Most people applied pesticides and herbicides to broad leaf weeds

When asked about how they disposed of leaves on their property, respondents gave the following answers:
4.5 % Left them on the ground, uncollected
0.3 % Raked them to the curb or storm sewer, but didn't collect them
10.2 % Burned them at the curb or on the lawn
4.9 % Burned them in a container and disposed of them with the garbage
3.2 % Raked them to the curb for scheduled leaf pickup
40.2 % Raked and bagged them for pickup
21.2 % Raked them into piles and put them into a compost pile
10.9 % Mulched them to enrich soil and form a protective land cover
4.2 % Did not respond

When asked about how plant clippings from their lots were disposed of, the followin answers were given:
24.8 % Left them where they fell, except on sealed surfaces where they are collecte
2.1 % Left them in the street,if they got there
2.8 % Raked them into the street
18 % Raked and bagged them for pickup
24.8 % Mulched or composted them
19.8 % Had no clippings
7.2 % Did not respond

A question concerning the respondents use of salt for ice control brought the following responses:
0.1 % Use salt to replace shoveling (thick application of salt on top of snow)
3.1 % Apply salt heavily, after shoveling
50.3 % Use salt only where there is glare ice
40.9 % Don't use salt at all
5.4 % Did not respond

The respondents were asked to indicate whether they had pets on the premises
42.8 % Responded yes
56.2 % Responded no
0.9 % Did not respond

Some of the _______ persons responding that they had   indicated that they had more than 1 pet. The total number of animals for those responding in this block was:

Small dogs 124
Large dogs 101
Cats 195
Other (including birds, gerbils, guinea pigs) 27
NR 8

When asked how the animal litter from their pets was treated, the following responses were given:

36.2 % Animal litter does not occur outside and that accumulating inside it disposed of with the garbage
0.8 % Do not pick it up outside and it is left on paved areas
38.4 % Do not pick it up outside and it is left on a grassy area
76.4 % Pick it up and put it in the garbage
7.8 % Pick it up and burn or compost it
2.6 % Did not respond

The respondents were asked to indicate if they have a sump pump. The response was:

20.7 % Yes
76.6 % No
7.8 % Did not respond

Of those indicating they had sump pumps, the following response was made as to the type of water pumped

4.2 NR
24.3 % Waste water from laundry facilities
0 % Backwash from swimming pool filter
9.5 % Water softner backwash
47 % Water leaking into my basement
14.8 % Other

Comments ______________________________

When asked to indicate where the sump pump in their home or business pumps the water, the following responses were given:

17.1 % Water pumped to house or building sewer which carries sanitary wastes
7.8 % Water pumped to storm sewer or roadside ditch
23.6 % Water pumped to respondents yard, which then runs into the storm sewer
39.4 % Water pumped to respondents yard, where it is fully absorbed
8.5 % Did not know
3.2 % Did not respond

A question was asked concerning the respondent washing their car(s) or other vehicle(s) at their home or business. The response was:

55.5 % Yes
42.3 % No
2.1 % Did not respond

When asked where the wash water goes, they answered:
30.9 % Directly into storm sewer
3.3 % Into sanitary sewer
0.5 % Water is treated and then goes into a storm sewer
63.9 % Is absorbed by the soil of their yard and/or unpaved driveway
1.2 % Did not respond

The respondents were also asked if they change the oil of their car (s) or other vehicle (s) at their home or business. The response was:

29 % Yes
68.2 % No
2.6 % Did not respond

When asked where they disposed of the used oil, they answered:
0.9 % It is left to run out onto the pavement or put into the storm sewer
7.1 % It is spread on soil
55.4 % It is collected with the garbage
36 % It is recycled by taking it to an oil collection station for processing to use
0.4 % Did not respond

_________ respondents made additional comments which are summarized below: